DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

Release Stamp

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WMA A-AX Performance Assessment Contaminant Fate and Transport Process Model to Evaluate Impacts to Groundwater

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Clearance Review	Ayers, Lynn M	*Ayers, Lynn M*	01/18/2021
Checker	Lee, Kearn (Pat)	*Lee, Kearn (Pat)*	10/01/2020
Document Control Approval	Alvarez, Efren	*Alvarez, Efren*	01/18/2021
Originator	Watson, David (Dj) J	*Watson, David (Dj) J*	09/29/2020
Quality Assurance	Lungu, Cris C	*Lungu, Cris C*	09/24/2020
Responsible Manager	Rutland, Paul L	*Rutland, Paul L*	10/01/2020

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Document Number	**Rev.**	**Title**
RPP-CALC-63248	00	WMA A-AX Performance Assessment Flow and Transport Process Model Support of the Sensitivity Analysis
RPP-ENV-61497	00	Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington
RPP-ENV-62206	00	Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington
RPP-RPT-60101	00	Model Package Report Flow and Contaminant Transport Numerical Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis

14. **Distribution**

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Singleton, Kristin M	CLOSURE & INTERIM MEASURES
Watson, David (Dj) J	CLOSURE & INTERIM MEASURES

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part I: Background Information

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Document Release Criteria in TFC-ENG-DESIGN-C-25 completed? (Attach checklist)	☐	☑	
If product contains pictures, safety review completed?	☐	☑	

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Subject Matter Expert	WRPS	01/13/2021	Watson, David (Dj) J Workflow data attached
Responsible Manager	WRPS	10/05/2020	Rutland, Paul L Workflow data attached
Other:			

Part V: IRM Clearance Services Review

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Additional Comments from Information Clearance Specialist Review?	☐	☒	Information Clearance Specialist Approval APPROVED By Lynn M. Ayers at 3:36 pm, Jan 13, 2021 Print Name/Signature/Date

When IRM Clearance Review is Complete – Return to WRPS Originator for Final Signature Routing (Part VI)

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part VI: Final Review and Approvals

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	Yes	N/A	
WRPS External Affairs	☒	☐	Mc Cune, Hal C - IDMS workflow data attached
WRPS Office of Chief Counsel	☒	☐	Roden, Mari L - IDMS workflow data attached
DOE – ORP Public Affairs/Communications	☒	☐	Tyree, Geoff T - IDMS workflow data attached
Other: DOE Office of Chief Counsel	☒	☐	Hellstrom, George W - IDMS workflow data attached
Other: DOE ORP SME	☒	☐	Lobos, Rodrigo A - IDMS workflow data attached

Comments Required for WRPS-Indicate Purpose of Document:

This document provides the basis for evaluation and review of the Waste Management Area (WMA) A-AX performance assessment three-dimensional vadose and saturated zone flow and contaminant transport process model calculations. The process model evaluation includes simulations of Tc-99 and I-129. The Tc-99 and I-129 simulations provide benchmark results to assist in the development of the vadose and saturated zone system model. The base case evaluation of the complete list of radionuclides and contaminants of potential concern occurs within the system model.

APPROVED
By Lynn M. Ayers at 3:36 pm, Jan 13, 2021

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<comments>DUE: Monday, October 19, 2020 - 9 AM Please review for public release, "WMA A-AX Performance Assessment Contaminant Fate and Transport Process Model to Evaluate Impacts to Groundwater," submitted by DJ Watson. Thank you, Lynn Ayers Information Clearance</comments>
</task>
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</workflow>

RPP-CALC-63164
Rev. 0

WMA A-AX PERFORMANCE ASSESSMENT CONTAMINANT FATE AND TRANSPORT PROCESS MODEL TO EVALUATE IMPACTS TO GROUNDWATER

Prepared by:

W. J. McMahon
CH2M HILL Plateau Remediation Company

Prepared for:
Washington River Protection Solutions, LLC

Date:

September 2020

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

ENVIRONMENTAL MODEL CALCULATION COVER PAGE

SECTION 1: COMPLETED BY RESPONSIBLE MANAGER OR DESIGNEE

Draft A
RELEASE/ISSUE

Project: WMA A-AX Performance Assessment

Date: 07/23/2019

Calculation Title and Description: WMA A-AX PERFORMANCE ASSESSMENT CONTAMINANT FATE AND TRANSPORT PROCESS MODEL TO EVALUATE IMPACTS TO GROUNDWATER

SECTION 2: COMPLETED BY PREPARER

Calculation No.: RPP-CALC-63164 Revision No.: Dft A

Revision History

ADD ROW

Revision No.	Description	Date	Affected Pages
Draft A	Initial Issue	07/23/2019	All

D

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1. Is document intended to be controlled within SmartPlant? ☒ Yes ☐ No
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Modeler-Required Training Completed:
Training Coordinator:

Print First and Last Name	Position	Signature	Date
Will Nichols	Training Coordinator	A. Day (actg)	7/23/19 ~~7/30/19~~

Software Installation and Checkout Certified:
Integration Lead:

Print First and Last Name	Position	Signature	Date
Will Nichols	Modeling Team Leader	A. Day (actg)	7/23/19 ~~7/25/19~~

SECTION 5: DOCUMENT REVIEW AND APPROVAL

	Print First and Last Name	Position	Signature	Date
Preparer:	W.J. McMahon	Sr. Eng.	W.J. McMahon	07/23/19
Checker:	Arun Wahi/Mike Connelly	Sr. Hydrogeo./Prin. Sci.	Arun K. Wahi	7/23/19
Senior Reviewer:	Mart Oostrom	Principal Hydrogeologist	M. Oostrom	7/23/19
Responsible Manager or Designee:	Robert Hiergesell	Manager	Robert Hiergesell	8/19/19

Page 1 of 1 A-6006-716 (REV 1)

1
2

EXECUTIVE SUMMARY

This environmental model calculation provides the basis for evaluation and review of the Waste Management Area (WMA) A-AX performance assessment three-dimensional vadose and saturated zone flow and contaminant transport process model calculations. The process model evaluation includes simulations of ^{99}Tc and ^{129}I. The ^{99}Tc and ^{129}I simulations provide benchmark results to assist in the development of the vadose and saturated zone system model (RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*). The base case evaluation of the complete list of radionuclides and contaminants of potential concern occurs within the system model (RPP-CALC-62538, *WMA A-AX Performance Assessment Groundwater Pathway Dose Calculation*).

RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis* documents the development of the three-dimensional vadose and saturated zone flow and contaminant transport process model. RPP-RPT-60101 contains the explanation of model development, which also serves to establish the basis of the process model to perform the calculations adequately. This basis includes determination of the process model inputs, as required by the documentation requirements associated with the preparation and issue of environmental calculations. RPP-RPT-60101 includes certain calculations that are necessary to demonstrate the soundness of the model. RPP-RPT-60101 also provides the technical basis for specific model parameters and boundary conditions, along with description of modeling assumptions. This document does not repeat that discussion. This environmental model calculation limits the discussion of input parameters and model development to specific items that either differ from those in or are not identified in RPP-RPT-60101.

The process model calculations are performed using the multi-processor capable extreme-scale Subsurface Transport Over Multiple Phases (eSTOMP)[1] simulator, except where the use of the serial Subsurface Transport Over Multiple Phases (STOMP)[2] simulator is specifically identified. The requirements of PRC-PRO-IRM-309, "Controlled Software Management" direct the control of all software used to implement the process model.

[1] Extreme-scale Subsurface Transport Over Multiple Phases (eSTOMP) is developed and distributed by Battelle Memorial Institute.

[2] Subsurface Transport Over Multiple Phases (STOMP) is developed and distributed by Battelle Memorial Institute.

CONTENTS

APPENDIX

ATTACHMENTS

FIGURES

TABLES

LIST OF TERMS

3-D	three-dimensional
AE&P	ancillary equipment and pipelines
ASME	American Society of Mechanical Engineers
CFR	*Code of Federal Regulations*
CHPRC	CH2M HILL Plateau Remediation Company
Ci	curie(s)
cm	centimeter(s)
cm/s	centimeters per second
CPGWM	Central Plateau Groundwater Model
Cr	chromium
DOE	U.S. Department of Energy
EMCF	environmental model calculation file
EMMA	Environmental Model Management Archive
EPA	U.S. Environmental Protection Agency
FEPs	features, events, and processes
ft	feet
g	gram(s)
h	hour(s)
H1	Hanford formation unit 1
H2	Hanford formation unit 2
HISI	Hanford Information System Inventory (software database)
HSU	hydrostratigraphic unit
in.	inch
kg	kilogram(s)

km	kilometer(s)
km^2	square kilometer(s)
m	meter(s)
eSTOMP	extreme-scale Subsurface Transport Over Multiple Phases simulator
m/s	meters per second
µg/L	micrograms per liter
MCL	Maximum Contaminant Limit
mg/kg	milligrams per kilogram
mL/g	milliliters per gram
mm/yr	millimeters per year
MPR	model package report
NAVD88	*North American Vertical Datum of 1988*
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PA	performance assessment
PA-TCT	power-averaging and tensorial connectivity-tortuosity
PNNL	Pacific Northwest National Laboratory
PoCal	point of calculation
RCRA	*Resource Conservation and Recovery Act of 1976*
SICO	Software Checkout and Installation Form
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases simulator
WMA	Waste Management Area
WRPS	Washington River Protection Solutions
yr	year

1 PURPOSE

The purpose of this environmental model calculation file (EMCF) is to document the Waste Management Area (WMA) A-AX performance assessment (PA) process model calculations of groundwater flow and transport of ^{99}Tc and ^{129}I associated with the residual waste in the tanks and ancillary equipment, including pipelines, after closure. The process model includes detailed consideration of specific processes expected to be of importance for the analysis (DOE-STD-5002-2017, *Disposal Authorization Statement and Tank Closure Documentation*), hence the term "process model." The WMA A-AX PA system model incorporates the results of the process model through an abstraction process, and includes the evaluation of the "base case" of all of the radionuclides and contaminants of potential concern. The results of the base case provide the basis for comparison to demonstrate that the performance objectives identified in Chapter IV of DOE M 435.1-1 *Radioactive Waste Management Manual* are not exceeded (DOE-STD-5002-2017). The use of the system model to conduct the base case limits the purpose of the WMA A-AX process model to providing estimates of future flow fields for the abstraction process, and providing contaminant concentrations in groundwater of ^{99}Tc and ^{129}I to calibrate and benchmark the system model.

1.1 OBJECTIVE

The objective of the initial WMA A-AX PA is to support activities associated with the retrieval of waste and the eventual closure of the tanks and ancillary equipment within WMA A-AX. The tanks and ancillary equipment are expected to contain residual levels of radioactive wastes after retrieval. The objective of this calculation is to estimate future contaminant concentrations in groundwater of ^{99}Tc and ^{129}I associated with waste remaining in tank residuals after closure of WMA A-AX. The ^{99}Tc and ^{129}I simulations provide benchmark results to assist in the development of the vadose and saturated zone system model (RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*), which includes the base case evaluation of the radionuclides and contaminants of potential concern (RPP-CALC-62538, *WMA A-AX Performance Assessment Groundwater Pathway Dose Calculation*). Although the residual inventory estimates include several radionuclides, ^{99}Tc is typically responsible for almost all of the beta-gamma dose equivalent associated with groundwater (water resources) protection per Title 40, *Code of Federal Regulations* (CFR), Part 141, "National Primary Drinking Water Regulations" (40 CFR 141) (e.g., see the results in RPP-ENV-58782, *Performance Assessment of Waste Management Area C, Hanford Site, Washington*), and ^{129}I can also be a significant dose contributor for some waste (e.g., RPP-RPT-59958, *Performance Assessment for the Integrated Disposal Facility, Hanford Site, Washington*).

The evaluation of potential radiological dose to groundwater receptors caused by releases from a closed facility containing radioactive waste typically includes the following: 1) release of radionuclides from that facility, 2) transport of those radionuclides through the environment, and 3) exposure to humans to environmental concentration levels of those radionuclides. The process model evaluation involves the post-closure impacts to the environment of the ^{99}Tc and ^{129}I remaining in the single-shell tanks (SSTs) and ancillary equipment, which includes 241-A-350, 241-A-417, 241-A-302A, 241-A-302B, 204-AR, 244-A, 244-AR, 241-AX-151, 241-AX-152, 241-AX-152/DS, diversions boxes, and pipeline residual waste. The PA includes calculations of potential doses to representative future members of the public and potential releases from the facility. The point of compliance for the WMA A-AX PA evaluation is the location where the highest calculated concentration or dose in the aquifer occurs beyond a 100-m buffer zone surrounding the disposed waste. The calculated concentration in the aquifer allows for some volume averaging, as discussed in Section 3.4.2 of this document and Section 3.1.8 of RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*.

This analysis does not consider contaminant release during WMA A-AX operations, such as unplanned releases from the tanks or ancillary equipment, including pipelines.

1.2 DOCUMENT STRUCTURE

This EMCF intends to read as a standalone document. However, that goal is balanced against duplicating content already contained in the supporting model package report (MPR) (RPP-RPT-60101). Therefore, this EMCF does not intend to provide exhaustive details of the context of the calculation, the background of the model development, or the generation of input data. The supporting MPR includes those items.

One of the functions of this EMCF is to document calculation details for review by an internal checker. The organization of the document may differ from that which may seem more logical in other contexts. Per EMCF requirements, the checker must be familiar with the type of calculations performed, and, in this case, the software structure and syntax of Subsurface Transport Over Multiple Phases (STOMP)[3] and extreme-scale Subsurface Transport Over Multiple Phases (eSTOMP)[4]. Other readers are strongly cautioned that such software details may not be explained in laymen's terms.

1.3 SUPPORTING DOCUMENTS

Document Number	Document Title
ICRP Publication 107:	Nuclear Decay Data for Dosimetric Calculations
PNNL-12030	STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide
PNNL-15782	STOMP Subsurface Transport Over Multiple Phases Version 4.0 User's Guide

[3] Subsurface Transport Over Multiple Phases (STOMP) is developed and distributed by Battelle Memorial Institute.

[4] Extreme-scale Subsurface Transport Over Multiple Phases (eSTOMP) is developed and distributed by Battelle Memorial Institute.

RPP-RPT-58693	Engineered System Data Package for Waste Management Area A-AX
RPP-RPT-60101	Model Package Report: Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis
RPP-RPT-60171	Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis
RPP-RPT-60885	Model Package Report System Model for the WMA A-AX Performance Assessment
RPP-CALC-62319	Residual Waste Source Inventory Term for the Waste Management Area A-AX Performance Assessment Inventory Case 1

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2 BACKGROUND

WMA A-AX includes the 241-A Tank Farm (A Farm), the 241-AX Tank Farm (AX Farm), associated ancillary equipment, and adjacent areas of soil contamination from unplanned releases. The WMA A-AX PA vadose and saturated zone process modeling only addresses the waste remaining in the tanks, ancillary equipment, and pipelines after retrieval concludes and closure of WMA A-AX occurs. Therefore, for this EMCF, the description of WMA A-AX, its history, and the closure activities assumed for WMA A-AX is limited to those items with relevance to the WMA A-AX PA tank residual process model calculations.

2.1 HISTORY

The 241-A Tank Farm contains six 75-ft diameter nominally 1,000,000-gal capacity SSTs that were constructed from January 1954 through October 1954. The 241-AX Tank Farm contains four 75-ft diameter nominally 1,000,000-gal capacity SSTs that were constructed from September 1963 through June 1964. By 2004, all the 100-series tanks were declared stabilized on an interim basis, indicating that each tank contained less than 50,000 gal of drainable interstitial liquid and less than 5,000 gal of supernate (HNF-SD-RE-TI-178, *Single-Shell Tank Interim Stabilization Record*), besides saltcake and sludge.

Constructed in 1966, the 244-AR Vault is located outside of WMA A-AX, but includes a canyon building that contains four tanks, a failed equipment cell and associated piping and equipment. The unit received waste sluiced from the 241-A and 241-AX Tank Farms. The vault was interim stabilized in 2003.

WMA A-AX includes a complex waste transfer system of pipelines (transfer lines), diversion boxes, vaults, valve pits, and other miscellaneous structures. There are approximately 9.1 miles (± 3 miles) of transfer pipelines attributed to A Farm, and approximately 7.9 miles (± 2.3 miles) attributed to AX Farm (RPP-15043, *Single-Shell Tank System Description*). There is uncertainty as to whether pipelines will be completely drained at the time of closure, or remain partially full from incomplete flushing and drainage or plugging (RPP-RPT-58693). The following diversion boxes are located in or associated with WMA A-AX: 241-A-151, 241-A-152, 241-A-153, 241-AX-151, 241 AX-152DS, 241-AX-153, 241-AX-155, 241-AY-151 and 241-AY-152 (RPP-RPT-58693). The following catch tanks are located in or associated with WMA A-AX: 241-A-350, 241-A-417, 241-A-302A, 241-A-302B, 204-AR catch tank, 244-A catch tank, 241-AX-151CT, and 241-AX-152CT (RPP-CALC-62319). For the purpose of the WMA A-AX PA modeling, the 244-AR Vault, the components of the waste transfer system, and the catch tanks are collectively referred to as ancillary equipment (RPP-CALC-62319).

Closure of WMA A-AX is expected to follow the same path as WMA C, for which RPP-RPT-41918, *Assessment Context for Performance Assessment for Waste in C Tank Farm Facilities after Closure* identified three major steps. In summary, closure requires the U.S. Department of Energy (DOE) to retrieve as much waste as technically possible from the tanks, fill the tanks with grout to stabilize and immobilize the residual waste to prevent further long-term degradation of the SSTs, and place an engineered surface cover to provide a barrier to infiltration and intrusion.

2.2 JUSTIFICATION OF METHODOLOGY

The WMA A-AX PA modeling is conducted in accordance with DOE implementation guidelines for DOE M 435.1-1. Existing regulations express compliance in terms of comparisons of single "base case" values to the performance objectives. This comparison provides a means to demonstrate that the closed facility adequately protects the environment and the public from exposure to radiation from radioactive materials per the requirements contained in DOE O 5400.1, *General Environmental Protection Program* and DOE O 5400.5, *Radiation Protection of the Public and the Environment*. The modeling includes a detailed evaluation of the groundwater concentrations and radionuclide arrival times during the 1,000-year compliance and 10,000-year sensitivity/uncertainty periods per DOE O 435.1, *Radioactive Waste Management*.

The process model evaluation includes best-estimate input data, which should represent central tendencies of the input data distributions (DOE-STD-5002-2017). Inclusion of less rigorously developed and more bounding (conservative) input data is acceptable when the maximum calculated dose relative to the performance objectives is low, or for parameters or features with little dose significance. However, if the base case maximum dose using bounding (conservative) input data approaches or exceeds one or more performance objectives, it then becomes important to revise the conservative estimates with best estimates based on more rigorously-developed data distributions.

The WMA A-AX PA analysis does not consider contaminant release during WMA A-AX operations, but only the post-closure impacts to the environment of the radionuclides and non-radiological contaminants remaining in the residual waste. The evaluation of suspected tank leaks and unplanned releases is outside the scope of the initial WMA A-AX PA.

3 METHODOLOGY

3.1 SELECTION OF TECHNICAL STAFF

The following staff performed the identified functions on the basis of their expertise and experience.

3.1.1 Project Management

Marcel P. Bergeron, Washington River Protection Solutions (WRPS), LCC.

M.A., Geology, Indiana University
B.A., Geology, University of Vermont

Marcel Bergeron has more than 35 years of experience in a wide variety of subsurface investigations and studies at radioactive and hazardous waste facilities and contaminated sites. He is experienced in planning and implementation of environmental characterization and risk assessment investigations in a variety of roles including as a technical contributor, a project and task manager, and a line manager. He has performed quantitative analysis of subsurface systems using analytical and numerical models and visualization tools. He has significant technical project experience in managing technical teams, schedules, and budgets for multi-disciplinary projects and communication of project results with clients, regulators, and stakeholders.

Robert A Hiergesell, WRPS, LCC.

M.S., Hydrogeology, University of Nebraska-Lincoln
B.S., Geology, Virginia Polytechnic Institute

Mr. Hiergesell has over 30 years of experience is in the areas of subsurface flow and transport simulation, groundwater monitoring, environmental remediation and performance assessment for low-level radioactive waste disposal. Prior to joining WRPS, Mr. Hiergesell was employed at the DOE Savannah River National Laboratory where he was the lead technical investigator for numerous environmental restoration and waste management projects.

3.1.2 Originators

William J. McMahon, Senior Engineer, Senior Vadose and Groundwater Modeler, CH2M HILL Plateau Remediation Company (CHPRC).

M.S., Agricultural Engineering, Texas A&M University
B.S., Agricultural Engineering, University of California, Davis

Mr. McMahon specializes in hydrologic data collection, analysis, and interpretation, and groundwater and vadose zone numerical modeling to support groundwater and vadose remedial projects. He has experience with a number of vadose zone and groundwater modeling packages. Mr. McMahon has been the one of the principal investigators in several PAs, focusing on the vadose and saturated flow and transport modeling using STOMP and eSTOMP code, groundwater pathway compliance calculations, sensitivity analysis, and document preparation. His other duties include directing hydrologic data collection efforts, analyzing and interpreting hydrologic data, assessing the effectiveness of groundwater remedial actions, developing work plans for data collection and interpretation, and performing numerical modeling to predict facility impacts to the aquifer to support remediation and construction decisions.

3.1.3 Checkers

Michael P. Connelly, Principal Scientist, TecGeo, Inc.

M.S., Geology, University of Utah
B.S., Geology, University of Utah

Mr. Connelly has over 33 years of experience in environmental geohydrology including project management, groundwater modeling, and using computer techniques to analyze and interpret field data for remedial action and site characterization activities. Mr. Connelly provided technical support in the post-processing of model output and preparation of graphics and visualizations used in the Hanford Site WMA C PA that are closely comparable to those used in this EMCF.

Arun Wahi, Senior Hydrogeologist, INTERA, Inc.

M.S., Hydrology, University of Arizona
B.S., Chemical Engineering, Carnegie Mellon University

Mr. Wahi has 15 years of consulting and research experience in the fields of hydrology, hydrogeology, and chemistry. He has led teams conducting modeling, hydrogeologic, geochemical, forensic, and remediation engineering analyses, as well as field investigations to perform soil and groundwater sampling and aquifer testing. He is a qualified user of STOMP/eSTOMP at the Hanford Site and has completed training in STOMP/eSTOMP and in WRPS quality assurance procedures. His experience includes performing numerical modeling of contaminant fate and transport of radionuclides and organic and inorganic contaminants in the saturated and unsaturated zones in support of DOE PAs. He led the pre-retrieval risk assessment of the Hanford Site AX Farm. He was the lead modeler for vadose zone/saturated zone fate and transport for the 2017 Hanford Site Integrated Disposal Facility PA.

3.1.4 Senior Reviewers

Mart Oostrom, Principal Hydrogeologist, INTERA, Inc.

Ph.D., Soil Physics, Auburn University
M.S., Soil Physics and Hydrogeology, Wageningen University
M.A., Teaching (Mathematics), University of Idaho
B.S., Soil Science, Wageningen University

Dr. Oostrom brings specialized expertise in the development and application of numerical models to evaluate groundwater flow and contaminant transport and the effectiveness of various environmental remediation methods and technologies. Some of his recent experience includes quantifying contaminant flux into groundwater at various deep-vadose zone waste disposal sites; conducting reservoir modeling for enhanced oil recovery and CO_2 sequestration; remediating the vadose zone using ammonium injection, soil dessication, and/or pore-water extraction; and developing a circulation method to quantify back-diffusion of dissolved contaminants into permeable sediment. Dr. Oostrom is co-author of the STOMP simulator, a mathematical model used to numerically simulate subsurface (multiphase) flow and transport as well as vadose zone and groundwater remediation. STOMP's target capabilities were guided by proposed or applied remediation activities at sites contaminated with volatile organic compounds and/or radioactive material. The simulator's modeling capabilities address a variety of subsurface environments, including nonisothermal conditions, fractured media, multiple-phase systems, nonwetting fluid entrapment, soil freezing conditions, nonaqueous phase liquids, first-order chemical reactions, radioactive decay, solute transport, dense brines, nonequilibrium dissolution, and surfactant-enhanced dissolution and mobilization of organics. Dr. Oostrom is Associate Editor of the Journal of Contaminant Hydrology and has authored over 100 refereed journal articles and contributed to book chapters on the subjects of multifluid flow, site characterization, remediation, and monitoring.

3.2 CONCEPTUAL MODEL

The following list of key vadose and saturated zone conceptual model components identified in RPP-RPT-60101 derives from the basic Hanford Site conceptual model developed in DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* :

- Model domain and boundary conditions
- Geologic setting
- Source term
- Vadose zone hydrogeology and contaminant transport
- Infiltration and recharge
- Geochemistry and sorption
- Groundwater domain.

For the evaluation of WMA A-AX closure, the PA conceptual model components must account for the source release of radionuclides and non-radiological contaminants from the grouted tanks, contaminant transport through engineered barriers, and contaminant transport through the natural environment, while accounting for decay and in-growth of daughter isotopes. Transport through engineered barriers must consider the degradation of the tank structures, flow of water through the waste in the tanks, and contaminant releases into the vadose zone. These processes include details of physical and chemical mechanisms on a refined local scale.

Sections 3.1.1 through 3.1.8 of RPP-RPT-60101 discuss in detail the key conceptual model components, and RPP-RPT-60885 and RPP-CALC-62319 provide further detail about the inventory release functions. The discussion includes the rationale and basis for each of the conceptual model components, the function that each conceptual model component serves in the PA process model, the assumptions associated with model components, and a qualitative assessment of the impact the component has on the process model results. That discussion is not repeated here.

3.3 MATHEMATICAL MODEL

The quantitative predictions necessary to achieve the process model objectives described in Section 1 are calculated using the equations and constitutive functions presented in PNNL-12030 and summarized in Section 3.1.4 of RPP-RPT-60101. The van Genuchten-Mualem constitutive relationship, the Richards equation (the water mass conservation equation in PNNL-12030) and the Advection-Dispersion equation (the solute mass conservation equation in PNNL-12030) represent the physical aspects of vadose and saturated zone flow and contaminant transport as they occur in the actual physical space.

The mathematics of the model utilize the integral volume finite difference method in STOMP and eSTOMP (PNNL-12030). This method involves adapting the physical elements of the conceptual model and its components to a finite difference approximation of the actual physical space. The integral volume finite difference approximation applies the governing equations and constitutive functions to an orthogonal computational domain that is divided into discrete nonoverlapping volumes. Intrinsic properties associated with the constitutive functions that represent the physical and geochemical systems and processes are defined for a point, referred to as a node, located at the geometric center of each discrete volume. These properties are assumed to be uniform throughout that volume. The governing conservation equations use these intrinsic properties to describe fluxes between the discrete volumes, and the accumulation or loss of the flux material within a volume. The equations are translated from partial differential form into algebraic equations that the STOMP and eSTOMP software solve.

The WMA A-AX finite difference model domain for flow and transport in the vadose zone and groundwater consists of a rectangular prism with dimensions of 812.6 m (2,666 ft) × 1,027.5 m (3,371 ft) × 119.5 m (392 ft), and which consists of 100 nodes × 120 nodes × 125 nodes along the three orthogonal axes. There are a total of 1.5 million nodes in the model domain, and each node represents a finite difference volume. The horizontal axes are rotated 45 degrees from the azimuth. The rotation aligns the x-axis in the general or approximate northwest to southeast direction of steady-state groundwater flow forecast by the Central Plateau Groundwater Model (CPGWM; CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 8.4.5*), as described in Appendix C of RPP-RPT-60101. Aligning an axis with the general direction of groundwater flow allows easier implementation of Neumann and Dirichlet type boundary conditions to the opposite boundaries.

3.4 CALCULATION PROCEDURE

The WMA A-AX tank residual simulations using STOMP or eSTOMP require running three separate stages of the model in sequence. The first stage is a long-term transient simulation of water flow resulting from the historic recharge conditions. The second stage, starting with the final moisture distribution provided by the first stage, simulates water flow during the Hanford operational period. The operational period begins in 1943 and includes the construction of WMA A-AX and the nearby surface disturbances that began in 1953, and ends with the assumed closure of WMA A-AX in 2050. The contaminant transport stage (stage 3) begins with the final moisture distribution provided by the second stage, and simulates flow and contaminant transport for 10,000 years, from 2050 to 12050. The use of results from a previous simulation as a starting point for another simulation is referred to as a "restart" condition in STOMP or eSTOMP.

3.4.1 Modeling Stages

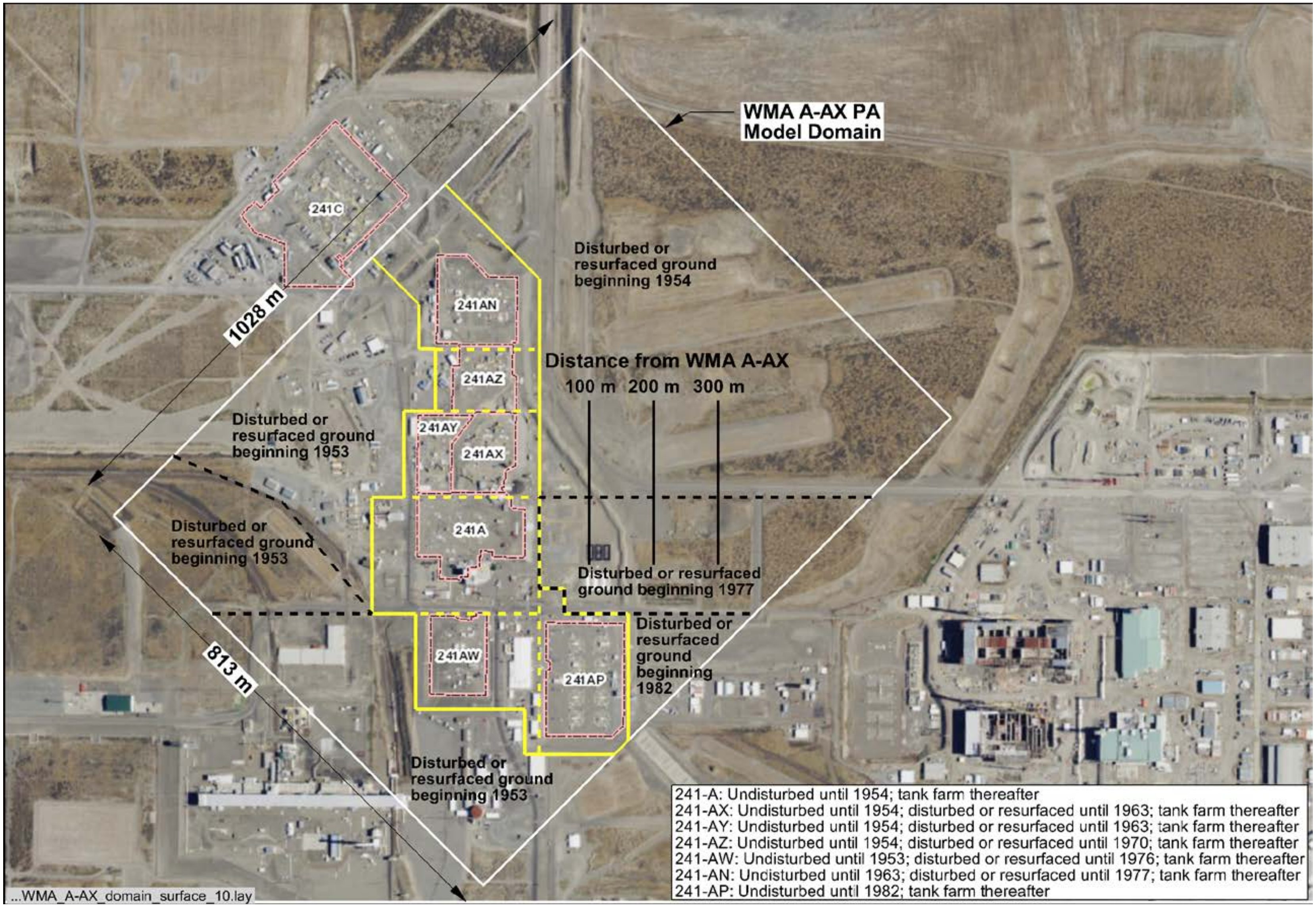
The three modeling stages correspond to the timeline associated with the surface of WMA A-AX: the time before construction of the tank farms when the surface remained undisturbed (pre-operations), the time during operations and prior to closure when backfill remains exposed at the surface (operations), and the time after WMA A-AX closes when a closure barrier covers the surface (post-closure). In general, the stages differ from one another because of the different recharge rates applied at the surface because of the changing surface conditions. The first stage also differs from the other two because the subsurface representation of the model domain does not include tank farm backfill or the A Farm or AX Farm tanks. The third stage differs from the other two because it includes contaminant transport, while the other two stages involve the flow of water only.

The first stage is needed to obtain near steady-state soil moisture conditions throughout the model domain for the start of the second stage representing the operations period. For WMA A-AX the first stage consists of two steps, each arbitrarily assigned 3,000 years to achieve steady state. During the first step, the recharge rate associated with pre-operations natural vegetation is applied across the top of the active model domain, which represents land surface. The northwest boundary condition is no-flow in the vadose zone, including the capillary fringe, and Neumann-type (specified flux) in the aquifer. The southeast boundary condition is no-flow in the vadose zone above the capillary fringe, and Dirichlet-type (specified pressure) in the capillary fringe and aquifer. The Dirichlet-type boundary condition applied in the model is called "seepage face," which, according to the STOMP nomenclature, refers to a boundary that is set to be in hydrostatic equilibrium vertically, and allows flow to exit the model only when the aqueous pressure exceeds the specified pressure. Although intended to simulate an exposed vertical face that seeps liquids, the seepage face boundary condition also represents a boundary that only permits flow out of the computational domain, while the pressure remains in hydrostatic equilibrium vertically. Appendix C of RPP-RPT-60101 presents a detailed description and explanation of the derivation of these boundary conditions, including the specified fluxes and pressure in the aquifer. The southwest and northeast boundary conditions are no-flow in the vadose zone and in the aquifer. The specified duration (3,000 years, which the results indicate is adequate to achieve steady state) and initial conditions for this step are arbitrary because the intent of the simulation is to achieve steady state, which is supposed to be independent of time and the initial conditions.

The second step of the first stage is identical to the first step, except that the results from the first step serve as a starting point or "restart," and the southwest and northeast boundary conditions change from no-flow in the aquifer and the layer immediately above the saturated zone to Dirichlet-type. The Dirichlet-type boundary condition applied here is called "initial condition," which, according to the STOMP and eSTOMP nomenclature, refers to a boundary pressure that is set and held at the value in the restart file of the adjacent node. This boundary condition allows flow to exit or enter the domain. The boundary conditions for the other vadose zone nodes in the four vertical planes remain no-flow. After this second step of the first stage, none of the boundary conditions in the four vertical planes of the model domain change. As with the first step, the intent of the simulation is to achieve steady state.

The second stage represents the period of Hanford operations, starting at 1943, until the assumed time of closure of WMA A-AX in 2050. For this period, the recharge changes to the operations values along the top surface of the model domain. Surface disturbance in parts of the area represented by the model domain began in 1953, although excavation for WMA A-AX did not begin until early 1954 (Figure 3-1). The surface conditions change according to the timetable presented or cited in Table 3-1, and the locations of the different areas identified in Table 3-1 are shown in Figure 3-1. Review of historical photographs presented in RPP-RPT-58693 shows that initial disturbance of the ground surface preceded the actual construction of several tank farms. Review of those photographs also provides a basis to infer years when the ground first became disturbed or reworked and resurfaced. Table 3-1 includes the times listed in Figure 4-3 of RPP-RPT-58693 when the Hanford-related construction activities appear to have disrupted the ground surface in and around the area of WMA A-AX. The dates the individual tank farms acquired their surface covering corresponds to the construction start dates presented in Table 4-2 of RPP-RPT-58693. Activity around the tank farms introduced different levels of disturbance to the surface. The large amount and long history of construction, operational, and waste disposal activity makes distinguishing areas where the ground remains disturbed but still allows vegetation to return and grow, and other areas that appear reworked such that vegetation does not grow, difficult. Therefore, for the WMA A-AX PA residuals analysis, all disturbed ground around the area of WMA A-AX is assumed to be reworked and resurfaced such that vegetation does not grow.

Figure 3-1. Plan View of Waste Management Area A-AX Performance Assessment Model Domain.



PA = performance assessment WMA = Waste Management Area

Table 3-1. Modeled Timetable of Surface Conditions in and around the Area of Waste Management Area A-AX.

Location in Model Domain	Undisturbed Ground	Disturbed or Resurfaced Surface	Tank Farm Surface
241-A Tank Farm	Until 1954	N/A	1954 to 2050
241-AX Tank Farm	Until 1954	1954 to 1963	1963 to 2050
241-AY Tank Farm*	Until 1954	1954 to 1963	1963 to 2050
241-AZ Tank Farm	Until 1954	1954 to 1970	1970 to 2050
241-AW Tank Farm	Until 1953	1953 to 1976	1976 to 2050
241-AN Tank Farm	Until 1963	1963 to 1977	1977 to 2050
241-AP Tank Farm	Until 1982	N/A	1982 to 2050
Disturbed or Resurfaced Area west of 241-A Tank Farm	Until 1953	1953 to 2050	N/A
Disturbed or Resurfaced Area west of 241-AY, 241-AZ, and 241-AN Tank Farms	Until 1953	1953 to 2050	N/A
Disturbed or Resurfaced Area east of 241-AX, 241-AZ, and 241-AN Tank Farms	Until 1954	1954 to 2050	N/A
Disturbed or Resurfaced Area east of 241-A Tank Farm	Until 1977	1977 to 2050	N/A
Disturbed or Resurfaced Area east of 241-AP Tank Farm	Until 1982	1982 to 2050	N/A
Disturbed or Resurfaced Area south of 241-AW Tank Farm	Until 1953	1953 to 2050	N/A

*Construction of 241-AY Tank Farm did not begin until 1968, but because of its small size and proximity to 241-AX Tank Farm, the 241-AY Tank Farm is assumed to follow the same timetable as 241-AX Tank Farm.

N/A = not applicable

The third stage represents the 10,000-year period after the assumed time of WMA A-AX closure. The specified duration coincides with the assumed beginning of the WMA A-AX post-closure period in 2050 and the end of the PA 10,000-year sensitivity/uncertainty evaluation period. The recharge rate changes to the post-closure values along the top surface of the model domain. In 2050, all tank farm surfaces are assumed to receive a surface barrier that limits the recharge rate to the design value for 500 years, and to the rate associated with undisturbed natural vegetation indefinitely after that. Revegetation of the disturbed and resurfaced areas is assumed to be completed in 2080, with the vegetation completing recovery in 30 years (by 2110).

Unlike the first two stages that involve only water flow, the third stage includes contaminant transport, and no contaminant mass is assumed to exist within the domain at the start of the third stage in 2050. The WMA A-AX post-closure stage treats each tank and the ancillary equipment and pipeline residual sources in each tank farm individually, although multiple sources may be grouped into a single simulation. The groundwater concentrations resulting from each source are summed according to the principle of superposition to produce volume or area plots of concentration, or time series concentration breakthrough curves at the points of calculation

(PoCals) identified and explained in Section 3.4.2. The principle of superposition also applies to the spatial distribution of the pore water concentrations in the vadose zone resulting from each source. The superposition and summing of the concentration results are post-processing steps that occur outside of STOMP or eSTOMP.

The first and second stage simulations, inputs, and files were documented, reviewed, and checked as part of the preparation of RPP-RPT-60101. The set of process model calculations associated with this EMCF begins with the third stage, using the restart files produced from the eSTOMP simulations conducted as part of the preparation of RPP-RPT-60101. This EMCF includes description of the first two modeling stages for completeness.

3.4.2 Points of Calculation

DOE PA requirements (DOE M 435.1-1, Chapter IV Section P) describe the point of compliance as the location where the impacts to groundwater are evaluated and compared to performance objectives and measures. The DOE PA manual and guide (DOE M 435.1-1 and DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1, Radioactive Waste Management Manual*, respectively) state that point of compliance is the point of highest projected dose or concentration beyond a 100-m buffer zone surrounding the disposed waste. The manual and guide do not identify how to determine the volume within which the concentration should be calculated, apart from indicating that the aquifer mixing must be consistent with State or local laws, regulations, or agreements. Section 3.1.8 in RPP-RPT-60101, which is summarized here, presents a detailed description and explanation of how the groundwater impacts are calculated in order to satisfy requirements in the DOE PA manual and Washington State law.

The description of the point of compliance presented in Section 3.1.8 in RPP-RPT-60101 indicates that there is a hypothetical line of analysis ~100 m from the WMA A-AX facility fence. The center of this line aligns with the centerline of the groundwater contamination plume produced by all of the WMA A-AX sources. The description in RPP-RPT-60101 further indicates that this line divides into nine segments that are ~30 m (100 ft) wide and ~5 m deep (16.4 ft), referred to as points of calculation (PoCals). The depth of 5 m represents the screened interval of a hypothetical groundwater monitoring well that extends 5 m (16.4 ft) below the water table. Concentrations calculated in the PoCal segments of the aquifer are assumed to be comparable to concentrations that would be measured by sampling the hypothetical groundwater monitoring wells at the PoCal segment locations. The particular PoCal where the highest concentration occurs becomes the point of compliance for the purpose of comparing the groundwater impacts to the DOE PA objectives and measures.

STOMP and eSTOMP input includes the ability to specify flux planes and have the output provide the rate and integrated total of mass of contaminant or volume of water through the specified plane. Post-processing outside STOMP or eSTOMP involves dividing the contaminant flux by the water flux at each PoCal flux plane for each time step to produce the concentration value time series. The concentration time series represents both a spatial (PoCal) and temporal (time step) average at each time step through each flux plane. Post-processing includes superposition to sum the concentrations of all of the sources at each PoCal flux plane to determine the peak concentration and identify the location and time of highest projected concentration from all sources.

Certain preliminary results of the process model analysis indicate that the highest concentration associated with a particular source, e.g., tank 241-AX-103 or the AX-Farm ancillary equipment and pipeline source, occurs in the outermost segment, i.e., PoCal 9. Therefore, the line of analysis now includes three additional segments added to the north of the original nine segments. Figure 3-2 shows the PoCals 100 m from the WMA A-AX fence, including three additional ones added to the north of the existing ones identified in RPP-RPT-60101. Figure 3-2 also shows PoCals along the WMA A-AX fence and 200 m from WMA A-AX, which are included to provide information about plume spreading and attenuation. Table 3-2 presents the width of each of the PoCals.

3.4.3 Model Evaluation

This section describes the test cases and evaluations conducted as part of model evaluation. DOE G 435.1-1 and Federal environmental model guidelines (EPA/100/K-09/003, *Guidance on the Development, Evaluation, and Application of Environmental Models*) describe model evaluation in terms of the determination of whether a model and its results are appropriate to use to inform a decision. While comparison of model results to reference data values is desirable, such comparisons are not feasible or practical for models providing estimates of impacts that occur several hundred or several thousand years into the future. Most process-oriented environmental models contain too many uncertain parameters to perform a meaningful calibration, and adjustment of parameters to improve the match between model results to reference data values is of questionable benefit (EPA/100/K-09/003). Therefore, evaluation of the WMA A-AX PA flow and transport model results consists of providing a qualitative assessment of the comparison of simulated vadose zone moisture content and WMA A-AX field-measured moisture content data (Section 3.4.3.1).

Other aspects of model evaluation include demonstrating that the model maintains mass balance of water and radionuclides (Section 3.4.3.2), and assessing the numerical accuracy of the simulation through tests intending to identify the possible impacts of numerical dispersion (Section 3.4.3.3). As indicated in RPP-RPT-60101, the impacts of numerical dispersion on the differential equation solutions are not typically large enough to negate the use of the model, but need to be recognized and managed to promote confidence in the overall value and usefulness of the results ("The Secret to Successful Solute Transport Modeling" [Konikow 2011]). RPP-RPT-60101 includes the evaluation of unintended impacts of the boundary conditions in the areas of interest around WMA A-AX. The results of that analysis indicate that the location of the boundaries does not adversely affect the evaluation of vadose and saturated zone flow and radionuclide transport associated with the WMA A-AX post-closure residual waste (Section 4.1 of RPP-RPT-60101). This EMCF does not repeat that evaluation. Section 7.1.2 includes the results and discussion of the test cases and evaluations conducted as part of model evaluation.

Figure 3-2. Points of Calculation 100 meters Downgradient of Waste Management Area A-AX.

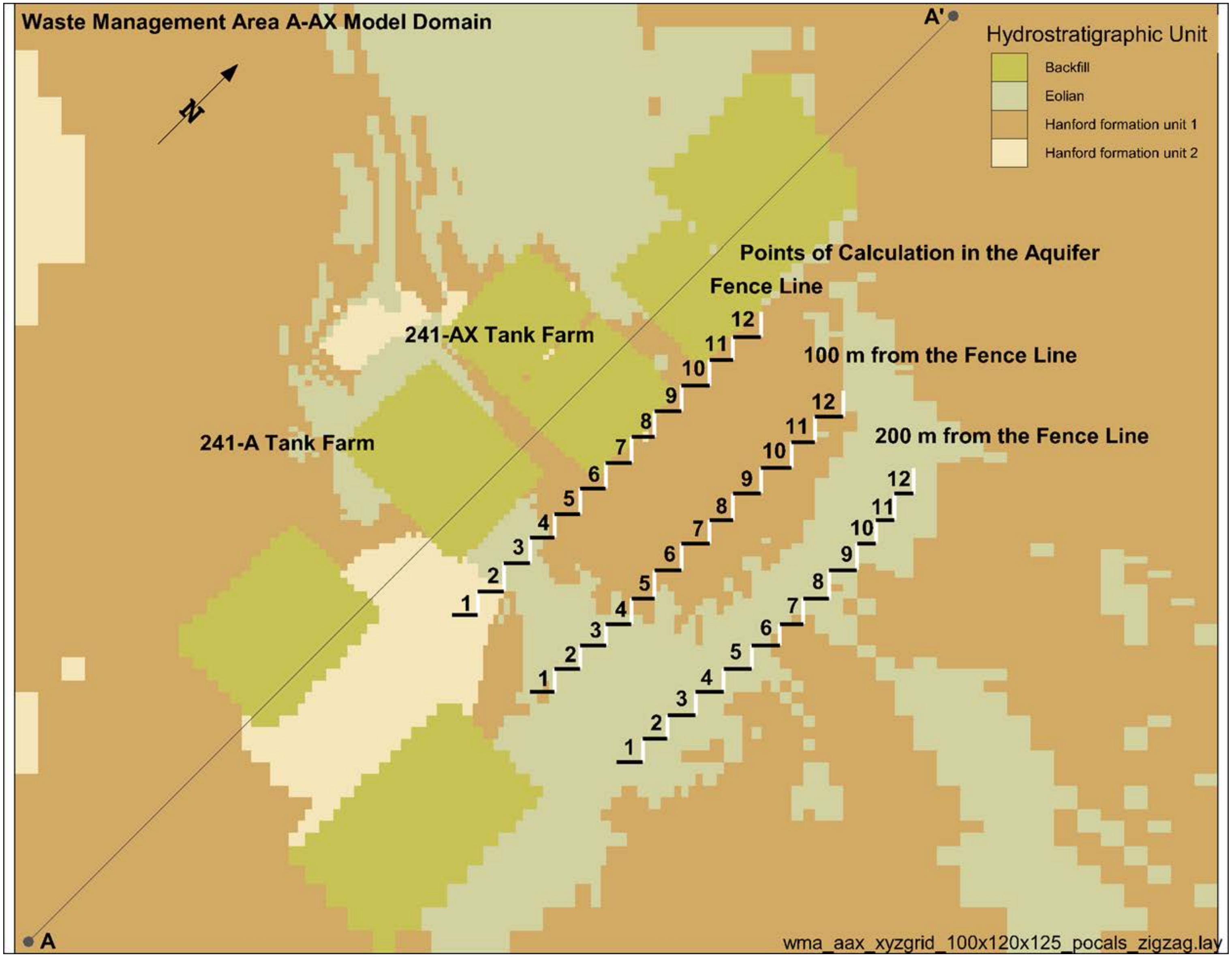


Table 3-2. Dimension of Widths for Point of Calculation Segments at the Fence Line, 100 meters, and 200 meters from Waste Management Area A-AX. (3 sheets)

Point of Calculation Segment At WMA A-AX Fence Line	Cell Face Orientation	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Subsegment Width (m)	Segment Normal Width (m)
1	east	75	75	46	50	21.982	29.7
	north	73	75	50	50	20	
2	east	72	72	51	55	22.227	32.7
	north	69	72	55	55	24	
3	east	68	68	56	59	22.297	31.3
	north	65	68	59	59	22	
4	east	64	64	60	63	20.85	28.9
	north	61	64	63	63	20	
5	east	60	60	64	68	21.982	31.1
	north	56	60	68	68	21.982	
6	east	55	55	69	73	21.982	31.1
	north	51	55	73	73	21.982	
7	east	50	50	74	78	21.982	31.1
	north	46	50	78	78	21.982	
8	east	45	45	79	82	19.562	29.4
	north	41	45	82	82	21.982	
9	east	40	40	83	86	23	31.8
	north	36	40	86	86	21.982	
10	east	35	35	87	90	24	32.5
	north	31	35	90	90	21.982	
11	east	30	30	91	93	20	28
	north	27	30	93	93	19.562	
12	east	26	26	94	96	24	32
	north	23	26	96	96	21.152	
Point of Calculation Segment 100 m from WMA A-AX	**Cell Face Orientation**	**Beginning I Index**	**Ending I Index**	**Beginning J Index**	**Ending J Index**	**Subsegment Width (m)**	**Segment Normal Width (m)**
1	east	82	82	60	63	20.85	28.9

Table 3-2. Dimension of Widths for Point of Calculation Segments at the Fence Line, 100 meters, and 200 meters from Waste Management Area A-AX. (3 sheets)

	north	81	82	63	63	20	
2	east	80	80	64	68	21.982	29.7
	north	79	80	68	68	20	
3	east	78	78	69	73	21.982	28.4
	north	77	78	73	73	18	
4	east	76	76	74	78	21.982	31.1
	north	74	76	78	78	22	
5	east	73	73	79	82	19.562	31
	north	70	73	82	82	24	
6	east	69	69	83	86	23	32.5
	north	66	69	86	86	23	
7	east	65	65	87	90	24	31.2
	north	62	65	90	90	20	
8	east	61	61	91	93	20	30.2
	north	57	61	93	93	22.627	
9	east	56	56	94	96	24	32.5
	north	52	56	96	96	21.982	
10	east	51	51	97	99	26	34
	north	47	51	99	99	21.982	
11	east	46	46	100	101	20	29.7
	north	42	46	101	101	21.982	
12	east	41	41	102	103	24	32.5
	north	37	41	103	103	21.982	
Point of Calculation Segment 200 m from WMA A-AX	**Cell Face Orientation**	**Beginning I Index**	**Ending I Index**	**Beginning J Index**	**Ending J Index**	**Subsegment Width (m)**	**Segment Normal Width (m)**
1	east	88	88	76	80	22.627	30.2
	north	87	88	80	80	20	
2	east	86	86	81	84	21	29
	north	85	86	84	84	20	
3	east	84	84	85	88	24	31.2

Table 3-2. Dimension of Widths for Point of Calculation Segments at the Fence Line, 100 meters, and 200 meters from Waste Management Area A-AX. (3 sheets)

	north	83	84	88	88	20	
4	east	82	82	89	92	24	31.2
	north	81	82	92	92	20	
5	east	80	80	93	95	24	31.2
	north	79	80	95	95	20	
6	east	78	78	96	98	24	30
	north	77	78	98	98	18	
7	east	76	76	99	100	20	29.7
	north	74	76	100	100	22	
8	east	73	73	101	102	22	32.6
	north	70	73	102	102	24	
9	east	69	69	103	104	24	33.2
	north	66	69	104	104	23	
10	east	65	65	105	105	16	25.6
	north	62	65	105	105	20	
11	east	61	61	106	106	16	27.7
	north	57	61	106	106	22.627	
12	east	56	56	107	107	16	27.2
	north	52	56	107	107	21.982	

WMA = Waste Management Area

3.4.3.1 Comparison of Simulated Vadose Zone Moisture Content and Waste Management Area A-AX Field-Measured Data. The process model hydraulic properties are used to simulate a vadose zone flow field and the simulation results are cross-checked against WMA A-AX field-measured moisture content data. WMA A-AX site characterization has included the collection of an extensive database of moisture content measurements of the various hydrostratigraphic units (HSUs) present. A summary of these measurements for the WMA A-AX area and associated statistics is provided in Table A-1 of RPP-ENV-58578, *Summary of the Natural System at Waste Management Area A-AX*. According to Table A-1 of RPP-ENV-58578, the average moisture content of the backfill samples is 9.50% by volume, the average moisture content of the Hanford formation unit 1 samples is 6.80% by volume, and the average moisture content of the Hanford formation unit 2 samples is 5.23% by volume. Section 7.1.2.1 includes the comparison of process model moisture content results to the moisture content measurements of the various HSUs.

3.4.3.2 Mass Balance. Ideally, the difference between the aqueous and radionuclide mass that enters and exits the model domain should equal the change in mass stored within the domain, with the radionuclide mass amounts accounting for losses due to decay. Truncation, round-off, and convergence tolerances all introduce potential discrepancies in the computation of mass, both aqueous and radionuclide, that enters, exits, and remains within the model domain. Calculation of the mass balance errors provides one indication of the level of error in the solution of the mass conservation equations and the overall accuracy of the results. Although the half-life of ^{99}Tc (211,100 years ["ICRP Publication 107: Nuclear Decay Data for Dosimetric Calculations" (ICRP 2008)]) is relatively long compared to the simulation period, mass lost to decay over 10,000 years (~3.2%) could be significant compared to any calculated mass imbalances and is included in the calculations. The half-life of ^{129}I is 15,700,000 years (ICRP 2008), and the mass lost to decay over 10,000 years (~0.04%) appears to be insignificant compared to any calculated mass imbalances and is not included in the calculations. For the WMA A-AX PA residual waste process model analysis, mass balance checks[5] include the following:

- Steady-state aqueous volume entering and exiting the model domain

- The difference between the aqueous volume that enters and exits the domain and the change in volume remaining within the domain relative to the amount of aqueous volume entering the domain for the period 1943 to 2050

- The difference between the aqueous volume that enters and exits the domain and the change in volume remaining within the domain relative to the amount of aqueous volume exiting the domain for the period 2050 to 3050

- The difference between the mass of ^{99}Tc that enters and exits the domain and the change in mass remaining within the domain for the period 2050 to the approximate time that the peak concentration of ^{99}Tc occurs at the 100-m point of compliance

- The difference between the mass of ^{99}Tc and ^{129}I that enters and exits the domain and the change in mass remaining within the domain for the period 2050 to 12050.

Section 7.1.2.2 includes the results of the mass balance checks.

3.4.3.3 Numerical Dispersion. Numerical solutions to the partial differential equations describing vadose and saturated zone flow and radionuclide transport are inexact approximations. Representation of the physical domain as a network of finite difference integral volumes, and the discretization of time into finite time steps, introduce inaccuracies into the solution. In the WMA A-AX PA vadose and saturated zone flow and transport model, the pore-water velocity is highly variable in time and space, and therefore no single numerical method is ideal or optimal over the entire domain of the problem. These approximations and imperfections introduce numerical errors into the solution in the form of numerical dispersion or solution oscillations.

[5] Although described as mass balance, the evaluation of water balance involves the calculated volume(s) of water, which is acceptable because the process model is a constant-temperature model and the water density is constant.

These numerical dispersion artifacts are not necessarily so large as to discredit or invalidate the solution, but do need to be recognized, controlled, and minimized to the extent practical (Konikow 2011). In general, decreasing time-step size and reducing the grid spacing decrease numerical dispersion, but at the cost of increased computation time, often to impractical levels. The Courant evaluation provides the check on numerical dispersion caused by time-step size. The Courant control feature in STOMP and eSTOMP provides a means to limit the allowable size of the time step used in the contaminant transport calculations. The Courant number (C_r) represents the ratio of the movement of a contaminant during a single time step and the distance between adjacent grid cells, i.e.,

$$C_r = \frac{v\Delta t}{\Delta x} \tag{3-1}$$

where v is the magnitude of the velocity of the water or contaminant (L/T), Δt is the time step (T), and Δx is the distance between adjacent grid cells (L). The Courant control in STOMP and eSTOMP allows the user to impose a limit on the allowable Courant number, which in turn imposes a limit on the time step used in the transport calculations. The impacts of numerical dispersion introduced into the results because of increases in the allowed time step size are then evaluated by comparing the results of simulations conducted with different degrees of Courant control. The Courant number evaluation imposes limits of 1, 10, and 25 to the Courant number to determine the sufficient degree of Courant control that balances solution accuracy with computational efficiency and practicality.

Evaluating numerical dispersion caused by grid size is more problematic. The WMA A-AX PA vadose and saturated zone flow and transport model grid is approximately 1.5 million nodes, so further refinement of the grid size may overwhelm the existing computing capability. Smaller grid spacing requires smaller time steps to satisfy the Courant number limit, which further increases the computational burden and calculation time.

For the PA numerical analysis, the evaluation of the numerical dispersion relies on an evaluation of the grid Peclet number. The grid Peclet number is cited in literature as a basis for stability criteria or accuracy criteria depending on the solution scheme. In numerical models, the grid Peclet number (Pe) depends on both the velocity of the fluid and a characteristic length associated with the grid. Although the Peclet number equation is a tensor, the component of the Peclet number parallel to the net direction of flow can be estimated using the equation:

$$Pe = \frac{v\Delta x}{(\alpha_l v + D^*)} \tag{3-2}$$

where v and Δx are defined as before in Equation 3-1, α_l is the dispersivity (L), and D^* is the diffusion coefficient (L^2/T). The denominator is known as the hydrodynamic dispersion tensor or coefficient of dispersion (L^2/T) and combines the effects of dispersion and diffusion. Models with high Peclet numbers are prone to numerical dispersion errors because of the large concentration gradients produced by the computation of the advective transport of the contaminant. <u>Computational Techniques for Fluid Dynamics</u> (Fletcher 1991) and PNNL-11216, *STOMP Subsurface Transport Over Multiple Phases Application Guide* indicate that the upper limit should remain below 2. Section 7.1.2.3 includes the discussion of the Peclet number evaluation.

3.4.3.4 Convergence Criteria. PETSc is currently the only approved solver option in CHPRC Build 6 of eSTOMP. Solute mass balance may not be maintained with the default PETSc settings for the convergence tolerance, but eSTOMP includes the option to specify values other than the defaults for the PETSc convergence tolerances. The convergence criteria tests demonstrate that the convergence tolerances applied in eSTOMP yield acceptable accuracy by showing that the maximum concentration results at the nine PoCals 100 m from WMA A-AX are comparable (within 5%) to results obtained using serial STOMP. Section 7.1.2.4 includes the discussion of the convergence criteria evaluation.

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4 ASSUMPTIONS AND INPUT

RPP-RPT-60101 includes the identification and discussion of the assumptions, data sources and data quality presented in this section. Appendix A of RPP-RPT-60101 provides the list of assumptions, and Section 5.1 of RPP-RPT-60101 presents the discussion of model limitations, neither of which is repeated here.

4.1 KEY ASSUMPTIONS

Appendix A of RPP-RPT-60101 provides a comprehensive listing of the assumptions relevant to this calculation. No additional assumptions pertinent for this calculation have been identified.

4.2 MODEL LIMITATIONS

Section 5.1 of RPP-RPT-60101 provides a discussion of the limitations relevant to this calculation. No additional limitations relevant to this calculation have been identified.

4.3 PROCESS MODEL INPUTS

This section presents a summary of the process model parameters and values assigned, including boundary and initial conditions. The tables in this section are structured to resemble the entries in the STOMP and eSTOMP input files to assist and expedite the checking process. In the following subsections, the use of the acronym STOMP refers to both STOMP and eSTOMP because the input file structure for these inputs in both codes is identical; a single line of input in the Solution Control Card invokes the PETSc solver when eSTOMP is used.

4.3.1 Gridding, Zonation and Initial Conditions

Table 4-1 presents the pattern of the spacing of the finite difference cells as identified in the STOMP grid card (~Grid Card). The horizontal node spacing used in the model domain varies between ~4.4 and 20 m to increase the resolution in the areas attempting to approximate the slopes associated with construction of WMA A-AX and the 100-series tanks. Within the confines of WMA A-AX, the horizontal grid cell dimensions ranged between ~4.4 and ~4.6 m to align the nodes and cells with the tanks. Outside of WMA A-AX, the grid cells expanded in size such that no adjoining grids differed in length by more than a factor of 1.5. Vertical spacing in the vadose zone ranged between 0.5 and 1.0 m, with the finer resolution occurring around the water table (~119.5 m *North American Vertical Datum of 1988* [NAVD88]) where the more highly resolved spacing attempts to capture the impacts of the silt layer and the fringe above the water table. Although the format of the STOMP grid card calls for the cell surface location of the first node followed by the count and cell size in each direction, Table 4-1 identifies the node index in each direction and the corresponding cell size. As discussed in Appendix C of RPP-RPT-60101, Layers k = 1 through k = 5 are assumed to be inactive.

Table 4-1. Horizontal and Vertical Spacing of the Finite Difference Cells in the Three Dimensional Waste Management Area A-AX Flow and Transport Model Domain. (3 sheets)

Cartesian Coordinate System Number of X-Direction Grid Cells (I Indices) = 100									
I Index	**Spacing**	**I Index**	**Spacing**	**I Index**	**Spacing**	**I Index**	**Spacing**	**I Index**	**Spacing**
1	20 m	2	20 m	3	20 m	4	20 m	5	16 m
6	16 m	7	16 m	8	12 m	9	12 m	10	12 m
11	12 m	12	10 m	13	10 m	14	10 m	15	8 m
16	8 m	17	8 m	18	8 m	19	8 m	20	6 m
21	6 m	22	6 m	23	6 m	24	5.152 m	25	5 m
26	5 m	27	5 m	28	5 m	29	5 m	30	4.562 m
31	4.355 m	32	4.355 m	33	4.355 m	34	4.355 m	35	4.562 m
36	4.355 m	37	4.355 m	38	4.355 m	39	4.355 m	40	4.562 m
41	4.355 m	42	4.355 m	43	4.355 m	44	4.355 m	45	4.562 m
46	4.355 m	47	4.355 m	48	4.355 m	49	4.355 m	50	4.562 m
51	4.355 m	52	4.355 m	53	4.355 m	54	4.355 m	55	4.562 m
56	4.355 m	57	4.355 m	58	4.355 m	59	4.355 m	60	4.562 m
61	5 m	62	5 m	63	5 m	64	5 m	65	5 m
66	5 m	67	6 m	68	6 m	69	6 m	70	6 m
71	6 m	72	6 m	73	6 m	74	6 m	75	8 m
76	8 m	77	8 m	78	10 m	79	10 m	80	10 m
81	10 m	82	10 m	83	10 m	84	10 m	85	10 m
86	10 m	87	10 m	88	10 m	89	10 m	90	10 m
91	10 m	92	10 m	93	10 m	94	10 m	95	12 m
96	16 m	97	16 m	98	20 m	99	20 m	100	20 m
Cartesian Coordinate System Number of Y-Direction Grid Cells (J Indices) =120									
J Index	**Spacing**	**J Index**	**Spacing**	**J Index**	**Spacing**	**J Index**	**Spacing**	**J Index**	**Spacing**
1	20 m	2	20 m	3	20 m	4	20 m	5	16 m
6	16 m	7	16 m	8	12 m	9	12 m	10	12 m
11	10 m	12	10 m	13	10 m	14	8 m	15	8 m
16	8 m	17	8 m	18	8 m	19	8 m	20	6 m
21	6 m	22	6 m	23	6 m	24	6 m	25	6 m
Cartesian Coordinate System									

Table 4-1. Horizontal and Vertical Spacing of the Finite Difference Cells in the Three Dimensional Waste Management Area A-AX Flow and Transport Model Domain. (3 sheets)

Number of Y-Direction Grid Cells (J Indices) =120 (continued)									
J Index	**Spacing**	**J Index**	**Spacing**	**J Index**	**Spacing**	**J Index**	**Spacing**	**J Index**	**Spacing**
26	6 m	27	6 m	28	6 m	29	5 m	30	5 m
31	5 m	32	5 m	33	4.794 m	34	4.562 m	35	4.355 m
36	4.355 m	37	4.355 m	38	4.355 m	39	4.562 m	40	4.355 m
41	4.355 m	42	4.355 m	43	4.355 m	44	4.562 m	45	4.355 m
46	4.355 m	47	4.355 m	48	4.355 m	49	4.562 m	50	4.355 m
51	4.355 m	52	4.355 m	53	4.355 m	54	4.562 m	55	4.6 m
56	5 m	57	5.25 m	58	6 m	59	6.047 m	60	6 m
61	5.25 m	62	5 m	63	4.6 m	64	4.562 m	65	4.355 m
66	4.355 m	67	4.355 m	68	4.355 m	69	4.562 m	70	4.355 m
71	4.355 m	72	4.355 m	73	4.355 m	74	4.562 m	75	4.355 m
76	4.355 m	77	4.355 m	78	4.355 m	79	4.562 m	80	5 m
81	5 m	82	5 m	83	5 m	84	6 m	85	6 m
86	6 m	87	6 m	88	6 m	89	6 m	90	6 m
91	6 m	92	6 m	93	8 m	94	8 m	95	8 m
96	8 m	97	8 m	98	8 m	99	10 m	100	10 m
101	10 m	102	12 m	103	12 m	104	12 m	105	16 m
106	16 m	107	16 m	108	20 m	109	20 m	110	20 m
111	20 m	112	20 m	113	20 m	114	20 m	115	20 m
116	20 m	117	20 m	118	20 m	119	20 m	120	20 m
Cartesian Coordinate System Number of Z-Direction Grid Cells (K Indices) = 125; Bottom Elevation = 95.25 m (NAVD88*)									
K Index	**Spacing**	**K Index**	**Spacing**	**K Index**	**Spacing**	**K Index**	**Spacing**	**K Index**	**Spacing**
1	3 m	2	2.5 m	3	2.25 m	4	2 m	5	1.75 m
6	1.75 m	7	1.5 m	8	1.25 m	9	1.25 m	10	1 m
11	1 m	12	1 m	13	0.75 m	14	0.75 m	15	0.75 m
16	0.75 m	17	0.5 m	18	0.5 m	19	0.5 m	20	0.5 m
21	0.5 m	22	0.5 m	23	0.5 m	24	0.5 m	25	0.5 m
26	0.5 m	27	0.5 m	28	0.5 m	29	0.5 m	30	0.5 m
Cartesian Coordinate System Number of Z-Direction Grid Cells (K Indices) = 125; Bottom Elevation = 95.25 m (NAVD88*) (continued)									

Table 4-1. Horizontal and Vertical Spacing of the Finite Difference Cells in the Three Dimensional Waste Management Area A-AX Flow and Transport Model Domain. (3 sheets)

K Index	Spacing	K Index	Spacing	K Index	Spacing	K Index	Spacing	K Index	Spacing
31	0.5 m	32	0.5 m	33	0.5 m	34	0.5 m	35	0.5 m
36	0.5 m	37	0.5 m	38	0.5 m	39	0.5 m	40	0.75 m
41	0.75 m	42	0.75 m	43	0.75 m	44	0.75 m	45	1 m
46	1 m	47	1 m	48	1 m	49	1 m	50	1 m
51	1 m	52	1 m	53	1 m	54	1 m	55	1 m
56	1 m	57	1 m	58	1 m	59	1 m	60	1 m
61	1 m	62	1 m	63	1 m	64	1 m	65	1 m
66	1 m	67	1 m	68	1 m	69	1 m	70	1 m
71	1 m	72	1 m	73	1 m	74	1 m	75	1 m
76	1 m	77	1 m	78	1 m	79	1 m	80	1 m
81	1 m	82	1 m	83	1 m	84	1 m	85	1 m
86	1 m	87	1 m	88	1 m	89	1 m	90	1 m
91	1 m	92	1 m	93	1 m	94	1 m	95	1 m
96	1 m	97	1 m	98	1 m	99	1 m	100	1 m
101	1 m	102	1 m	103	1 m	104	1 m	105	1 m
106	1 m	107	1 m	108	1 m	109	1 m	110	1 m
111	1 m	112	1 m	113	1 m	114	1 m	115	1 m
116	1 m	117	1 m	118	1 m	119	1 m	120	1 m
121	1 m	122	1 m	123	1 m	124	1 m	125	1 m

*NAVD88, 1988, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland.

Source: Table 4-1 in RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis.*

The distribution of the WMA A-AX HSUs within the computational domain is declared via the Rock/Soil Zonation Card (Table 4-2). Each stage of the modeling, steady-state preconditioning, operations period, and post-closure period, utilizes a different external file, referred to as zonation files, “wma_aax_pre_hanford_acm1_ccu_19.zon,” “wma_aax_operational_acm1_ccu_19.zon,” and, “wma_aax_postclosure_acm1_ccu_19.zon,” respectively, generated from the interpolation of the geologic model developed in RPP-RPT-60171 onto the STOMP spatial grid. Each rock/soil number in these external files corresponds to the HSUs identified in Table 4-2. The tank farm backfill units did not exist prior to construction of the tank farms and are therefore not applicable to the steady-state preconditioning stage. The backfill in the double-shell tank farms is assumed to resemble the backfill in A Farm.

The Initial Conditions Card (~Initial Conditions Card) is used to approximate the state of the system within the model domain at the start of the simulation. For these simulations, the aqueous pressure is specified throughout the model domain, and the gas pressure is assumed to be in equilibrium with the aqueous pressure. The aqueous saturation is computed from the aqueous pressure using the capillary pressure functions specified in the saturation function card. Only the first steady-state preconditioning simulation requires initial conditions specified in the initial conditions card; the other simulation periods derive their initial conditions from restart files generated at the conclusion of the preceding period. As indicated in Table 4-3, the initial pressure distribution is assumed to be in hydrostatic equilibrium vertically, with the water table located approximately 119.5 m NAVD88.

4.3.2 Soil Hydraulic Properties

Input cards identifying, describing, and quantifying the soil hydraulic properties of the WMA A-AX HSUs include the Mechanical Properties Card (~Mechanical Properties Card), Hydraulic Properties Card (~Hydraulic Properties Card), Saturation Function Card (~Saturation Function Card), and Directional Aqueous Relative Permeability Cards (~X-Aqueous Relative Permeability Card, ~Y-Aqueous Relative Permeability Card, and ~Z-Aqueous Relative Permeability Card). The soil hydraulic property cards must include entries for each HSU (rock/soil type) referenced in the Rock/Soil Zonation Card. Each HSU is described as an equivalent homogeneous medium. Hydraulic property values associated with equivalent homogeneous media represent the mean or the bulk flow characteristics of the HSU. As discussed in Section 3.1.7 of RPP-RPT-60101, HSUs that include portions above and below the water table have those portions designated separately. Different methods are used to determine the hydraulic parameters for the saturated and vadose portions of these HSUs and therefore certain hydraulic parameters for the same HSU differ, depending on whether the portion is above or below the water table.

The Mechanical Properties Card (Table 4-4) identifies the values applicable to the particle density, porosity, specific storativity or compressibility, and identifies the tortuosity functions for each HSU. Section 3.1.4.5.2 of RPP-RPT-60101 presents the development of the particle density parameter values included in Table 4-4, which are determined using the effective bulk density estimates presented in Section B.6.1 in Appendix B of RPP-RPT-60101. The total and diffusive porosity estimates of the vadose HSUs included in Table 4-4 are assumed to equal the effective saturated moisture content values (θ_s^e) presented in Table 3-2 of RPP-RPT-60101, and development of the effective saturated moisture content values is discussed in Section 3.1.4.3 of RPP-RPT-60101. Section 3.1.7 and Appendix C of RPP-RPT-60101 describes the development of the porosity values applicable to the saturated portion of the HSUs. Section 3.1.7 of RPP-RPT-60101 includes the explanation for the specified compressibility volume and associated values, and Section 3.1.4.5.3 of RPP-RPT-60101 describes the tortuosity function identified in Table 4-4.

Table 4-2. Hydrostratigraphic Distribution of the Finite Difference Cells in the Three-Dimensional Waste Management Area A-AX Flow and Transport Model Domain.

Rock/Soil Identifying Number	Steady State Periods	Operations Period	Post-Closure Period
	Zonation file unformatted, wma_aax_pre_hanford_acm1_ccu_19.zon	**Zonation file unformatted, wma_aax_operational_acm1_ccu_19.zon**	**Zonation file unformatted, wma_aax_postclosure_acm1_ccu_19.zon**
	Hydrostratigraphic Unit	**Hydrostratigraphic Unit**	**Hydrostratigraphic Unit**
0	Inactive[a]	Inactive[a]	Inactive[a]
1	Basalt[b]	Basalt[b]	Basalt[b]
2	Ringold A Aquifer	Ringold A Aquifer	Ringold A Aquifer
3	Ringold LM Aquifer	Ringold LM Aquifer	Ringold LM Aquifer
4	Ringold E Aquifer	Ringold E Aquifer	Ringold E Aquifer
5	Cold Creek Gravel Aquifer	Cold Creek Gravel Aquifer	Cold Creek Gravel Aquifer
6	Ringold A Vadose	Ringold A Vadose	Ringold A Vadose
7	Ringold LM Vadose	Ringold LM Vadose	Ringold LM Vadose
8	Ringold E Vadose	Ringold E Vadose	Ringold E Vadose
9	Cold Creek Gravel Vadose	Cold Creek Gravel Vadose	Cold Creek Gravel Vadose
10	Cold Creek Silt Vadose	Cold Creek Silt Vadose	Cold Creek Silt Vadose
11	H3 Gravelly Sand Vadose	H3 Gravelly Sand Vadose	H3 Gravelly Sand Vadose
12	H2 Sand	H2 Sand	H2 Sand
13	H1 Gravelly Sand	H1 Gravelly Sand	H1 Gravelly Sand
14	Eolian	Eolian	Eolian
15	Not present	A Farm Backfill	A Farm Backfill
16	Not present	AX Farm Backfill[c]	AX Farm Backfill[c]

Note: The zonation files also serve for the ~Inactive Nodes Card.

See Section 3.1.2 in RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis* for a bullet list of the hydrostratigraphic units listed in this table.

H1 = Hanford formation unit 1 H2 = Hanford formation unit 2 H3 = Hanford formation unit 3

[a]Inactive cells include vertical layers 1-5, basalt cells (after renumbering), and above-ground surface cells.

[b]In the three-dimensional (3-D) geologic model described in RPP-RPT-60171, *Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis*, the number identifying basalt is 1, but all basalt cells in the zonation files are renumbered with 0.

[c]In the 3-D geologic model described in RPP-RPT-60171, the number identifying A Farm and AX Farm backfill is 15 but backfill cells in the steady-state zonation files are renumbered with 13 (H1 Gravelly Sand), and AX Farm backfill cells in the operations and post-closure zonation files are renumbered with 16.

Table 4-3. Initial Conditions of the Finite Difference Cells in the Three-Dimensional Waste Management Area A-AX Flow and Transport Model Domain.

Simulation Period	Saturation-Pressure Variable Set Option	Number of Initial Conditions	Pressure Variable	Pressure	Pressure Units	Z-Direction Gradient	Z-Direction Gradient Units	I, J, K Index Start and End
Steady State Period 1	Gas Pressure, Aqueous Pressure	1	Aqueous Pressure	324087.78	Pa	-9793.52	1/m	1, 100, 1, 120, 1, 125
Steady State Period 2	Gas Pressure, Aqueous Pressure	0	N/A	N/A	N/A	N/A	N/A	N/A
Operations Period	Gas Pressure, Aqueous Pressure	0	N/A	N/A	N/A	N/A	N/A	N/A
Post-Closure Period	Gas Pressure, Aqueous Pressure	0	N/A	N/A	N/A	N/A	N/A	N/A

N/A = not applicable

Steady State Period 2, Operations Period, and Post-Closure Period derive their initial conditions from restart files generated at the conclusion of the preceding period.
Node Pressure calculated as follows:
West boundary water table elevation = 119.5 m *North American Vertical Datum of 1988*; East boundary water table elevation = 119.5 m - 5.00E-06 m/m × 812.6 m = 119.495937* m (Table 4-1 in RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis* and Appendix C, pg. C-33 in RPP-RPT-60101).
101325 Pa + (119.495937* m - 96.75 m) × 9793.52 Pa/m = 324087.78 Pa (Appendix D, pg. D-3 in RPP-RPT-60101).
*The precision expressed in the value does not denote confidence in the quantitative estimates of the real-world system to the indicated level of accuracy, but describes the precision necessary to verify the calculation.

Table 4-4. Soil Hydraulic Properties Identified in the Mechanical Properties Card of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 sheets).

Hydrostratigraphic Unit	Particle Density[a]	Particle Density Units[a]	Total Porosity[b]	Diffusive Porosity[b]	Specified Compressibility[c]	Compressibility[c]	Compressibility Units[c]	Tortuosity Function[d]
Basalt	2.65	g/cm^3	0.0001	0.0001	Pore	1.00E-07	1/Pa	Millington and Quirk
Ringold A Aquifer	2.60	g/cm^3	0.08	0.08	Pore	1.00E-07	1/Pa	Millington and Quirk
Ringold LM Aquifer	2.82	g/cm^3	0.08	0.08	Pore	1.00E-07	1/Pa	Millington and Quirk
Ringold E Aquifer	2.60	g/cm^3	0.08	0.08	Pore	1.00E-07	1/Pa	Millington and Quirk
Cold Creek Gravel Aquifer	2.60	g/cm^3	0.25	0.25	Pore	1.00E-07	1/Pa	Millington and Quirk
Ringold A Vadose	2.60	g/cm^3	0.174E+00	0.174E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
Ringold LM Vadose	2.82	g/cm^3	0.435E+00	0.435E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
Ringold E Vadose	2.60	g/cm^3	0.174E+00	0.174E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
Cold Creek Gravel Vadose	2.60	g/cm^3	0.174E+00	0.174E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
Cold Creek Silt Vadose	2.82	g/cm^3	0.435E+00	0.435E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
H3 Gravelly Sand Vadose	2.60	g/cm^3	0.174E+00	0.174E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
H2 Sand	2.71	g/cm^3	0.384E+00	0.384E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
H1 Gravelly Sand	2.71	g/cm^3	0.384E+00	0.384E+00	Pore	1.00E-07	1/Pa	Millington and Quirk

Table 4-4. Soil Hydraulic Properties Identified in the Mechanical Properties Card of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 sheets).

Hydrostratigraphic Unit	Particle Density[a]	Particle Density Units[a]	Total Porosity[b]	Diffusive Porosity[b]	Specified Compressibility[c]	Compressibility[c]	Compressibility Units[c]	Tortuosity Function[d]
Eolian	2.71	g/cm^3	0.384E+00	0.384E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
A Farm Backfill	2.60	g/cm^3	0.174E+00	0.174E+00	Pore	1.00E-07	1/Pa	Millington and Quirk
AX Farm Backfill	2.71	g/cm^3	0.384E+00	0.384E+00	Pore	1.00E-07	1/Pa	Millington and Quirk

[a] Particle density and particle density units are discussed and described in Section 3.1.4.5.2 of RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*.

[b] Total and diffusive porosity are assumed to equal the effective saturated moisture content values (θ_s^e) identified in Table 3-2 of RPP-RPT-60101.

[c] Specified compressibility volume and values are discussed and described in Section 3.1.7 of RPP-RPT-60101.

[d] "Millington and Quirk" are input file keywords used to invoke the tortuosity function in Subsurface Transport Over Multiple Phases (STOMP, developed and distributed by Battelle Memorial Institute). The tortuosity function is discussed and described in Section 3.1.4.5.3 of RPP-RPT-60101 and in PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*.

The Hydraulic Properties Card (Table 4-5) identifies the saturated hydraulic conductivity values applicable to each HSU. As indicated in Table 4-5, saturated hydraulic conductivity is specified for each HSU and for each of the three principal directions. Section 3.1.4.4 and Appendix B of RPP-RPT-60101 describe the development of the combined power-averaging and tensorial connectivity-tortuosity (PA-TCT) model, and its application to estimate the anisotropic hydraulic conductivity tensor applicable to each vadose HSU. Appendix C of RPP-RPT-60101 describes the development of the saturated hydraulic conductivity values applicable to the saturated portion of the HSUs.

The Saturation Function Card (Table 4-6) identifies the functional model and associated parameters that relate the aqueous capillary pressure to aqueous saturation for each HSU. Although saturation function models and parameters must be specified for each HSU, they only pertain to the vadose zone and are inconsequential for the saturated zone. The WMA A-AX PA modeling utilizes the van Genuchten retention function to describe quantitatively the aqueous capillary pressure - aqueous moisture content characteristic curve. The van Genuchten model involves three curve fitting parameters: van Genuchten α, van Genuchten n, and van Genuchten m. The default option in STOMP is to set $m = 1 - 1/n$, and the WMA A-AX PA modeling adopts this default (PNNL-12030 and PNNL-15782). The implementation of the van Genuchten function in STOMP requires that another parameter, the residual saturation, be specified for each HSU (PNNL-12030 and PNNL-15782). The residual saturation, defined as the saturation at which the aqueous relative permeability approaches zero, is determined from the residual and saturated moisture content values found in Table 3-2 of RPP-RPT-60101, i.e., $S_r = \theta_r^e/\theta_s^e$. Section 3.1.4.2 and Appendix B of RPP-RPT-60101 describe the process of estimating the van Genuchten curve-fitting parameters and the residual moisture content of each HSU.

The Directional Aqueous Relative Permeability Cards (Table 4-7) identify the functional model and associated parameters that relate the aqueous relative permeability to effective aqueous saturation for each HSU. In the STOMP input files, the cards are separated into directions, i.e., ~X-Direction Aqueous Relative Permeability Card, ~Y-Direction Aqueous Relative Permeability Card, and ~Z-Direction Aqueous Relative Permeability Card, but the three cards and entries have been compressed into Table 4-7. Although aqueous relative permeability models and parameters must be specified for each HSU, they only pertain to the vadose portion of HSUs, and are inconsequential for the saturated portions of HSUs. The Mualem aqueous relative permeability function is strictly applicable to the van Genuchten function and is dependent on the capillary pressure - aqueous moisture content characteristic curve (PNNL-12030 and PNNL-15782). The modified Mualem model involves a pore scale parameter specified in each of the three coordinate directions to evaluate the anisotropy in relative permeability or unsaturated hydraulic conductivity using the tensorial-connectivity-tortuosity model described in Section 3.1.4.4 and Appendix B of RPP-RPT-60101. The saturated portions of the HSUs, where the pore scale parameter value is inconsequential, invoke the default value in STOMP, which is 0.5.

Table 4-5. Soil Hydraulic Properties Identified in the Hydraulic Properties Card of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model.

Hydrostratigraphic Unit	X-Direction Hydraulic Conductivity	Hydraulic Conductivity Units	Y-Direction Hydraulic Conductivity	Hydraulic Conductivity Units	Z-Direction Hydraulic Conductivity	Hydraulic Conductivity Units
Basalt	1.00E-08	cm/s	1.00E-08	cm/s	1.00E-08	cm/s
Ringold A Aquifer	1.00E+00	m/d	1.00E+00	m/d	1.00E-01	m/d
Ringold LM Aquifer	8.00E-03	m/d	8.00E-03	m/d	8.00E-04	m/d
Ringold E Aquifer	3.56E+01	m/d	3.56E+01	m/d	3.56E+00	m/d
Cold Creek Gravel Aquifer	1.82E+04	m/d	1.82E+04	m/d	1.381E+03	m/d
Ringold A Vadose	4.671E-02	cm/s	4.671E-02	cm/s	7.714E-03	cm/s
Ringold LM Vadose	8.37E-05	cm/s	8.37E-05	cm/s	6.68E-05	cm/s
Ringold E Vadose	4.671E-02	cm/s	4.671E-02	cm/s	7.714E-03	cm/s
Cold Creek Gravel Vadose	4.671E-02	cm/s	4.671E-02	cm/s	7.714E-03	cm/s
Cold Creek Silt Vadose	8.37E-05	cm/s	8.37E-05	cm/s	6.68E-05	cm/s
H3 Gravelly Sand Vadose	4.671E-02	cm/s	4.671E-02	cm/s	7.714E-03	cm/s
H2 Sand	6.196E-03	cm/s	6.196E-03	cm/s	6.157E-03	cm/s
H1 Gravelly Sand	6.196E-03	cm/s	6.196E-03	cm/s	6.157E-03	cm/s
Eolian	6.196E-03	cm/s	6.196E-03	cm/s	6.157E-03	cm/s
A Farm Backfill	4.671E-02	cm/s	4.671E-02	cm/s	7.714E-03	cm/s
AX Farm Backfill	6.196E-03	cm/s	6.196E-03	cm/s	6.157E-03	cm/s

Vadose zone hydrostratigraphic unit values from Table 3-3 in Section 3.1.4.4 of RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis.*
Aquifer hydrostratigraphic unit values from Table 3-9 in Section 3.1.7 of RPP-RPT-60101.

H1 = Hanford formation unit 1 H2 = Hanford formation unit 2 H3 = Hanford formation unit 3

Table 4-6. Soil Hydraulic Properties Identified in the Saturation Function Card of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model.

Hydrostratigraphic Unit	Saturation Function Option	van Genuchten α	van Genuchten α Units	van Genuchten n	Residual Saturation*
Basalt	Nonhysteretic van Genuchten	0.0001	1/cm	1.0001	0.00001
Ringold A Aquifer	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
Ringold LM Aquifer	Nonhysteretic van Genuchten	6.545E-03	1/cm	1.815E+00	1.749E-01
Ringold E Aquifer	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
Cold Creek Gravel Aquifer	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
Ringold A Vadose	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
Ringold LM Vadose	Nonhysteretic van Genuchten	6.545E-03	1/cm	1.815E+00	1.749E-01
Ringold E Vadose	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
Cold Creek Gravel Vadose	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
Cold Creek Silt Vadose	Nonhysteretic van Genuchten	6.545E-03	1/cm	1.815E+00	1.749E-01
H3 Gravelly Sand Vadose	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
H2 Sand	Nonhysteretic van Genuchten	6.419E-02	1/cm	1.698E+00	7.552E-02
H1 Gravelly Sand	Nonhysteretic van Genuchten	6.419E-02	1/cm	1.698E+00	7.552E-02
Eolian	Nonhysteretic van Genuchten	6.419E-02	1/cm	1.698E+00	7.552E-02
A Farm Backfill	Nonhysteretic van Genuchten	8.859E-02	1/cm	1.271E+00	2.184E-02
AX Farm Backfill	Nonhysteretic van Genuchten	6.419E-02	1/cm	1.698E+00	7.552E-02

*Residual saturation (S_r) is calculated by dividing the effective residual moisture content (θ_r^e) value by the effective saturated moisture content (θ_s^e) value found in Table 3-2 of RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*, i.e., $S_r = \theta_r^e/\theta_s^e$.

Source: Section 3.1.4.3 of RPP-RPT-60101.

H1 = Hanford formation unit 1 H2 = Hanford formation unit 2 H3 = Hanford formation unit 3

Table 4-7. Soil Hydraulic Properties Identified in the Directional Aqueous Relative Permeability Card of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model.

Hydrostratigraphic Unit	Relative Permeability Model X and Y Directions	Pore Scale Parameter*	Relative Permeability Model Z Direction	Pore Scale Parameter*
Basalt	Modified Mualem	0.500	Modified Mualem	0.500
Ringold A Aquifer	Modified Mualem	0.500	Modified Mualem	0.500
Ringold LM Aquifer	Modified Mualem	0.500	Modified Mualem	0.500
Ringold E Aquifer	Modified Mualem	0.500	Modified Mualem	0.500
Cold Creek Gravel Aquifer	Modified Mualem	0.500	Modified Mualem	0.500
Ringold A Vadose	Modified Mualem	0.637	Modified Mualem	-0.225
Ringold LM Vadose	Modified Mualem	0.167	Modified Mualem	0.407
Ringold E Vadose	Modified Mualem	0.637	Modified Mualem	-0.225
Cold Creek Gravel Vadose	Modified Mualem	0.637	Modified Mualem	-0.225
Cold Creek Silt Vadose	Modified Mualem	0.167	Modified Mualem	0.407
H3 Gravelly Sand Vadose	Modified Mualem	0.637	Modified Mualem	-0.225
H2 Sand	Modified Mualem	-0.683	Modified Mualem	0.375
H1 Gravelly Sand	Modified Mualem	-0.683	Modified Mualem	0.375
Eolian	Modified Mualem	-0.683	Modified Mualem	0.375
A Farm Backfill	Modified Mualem	0.637	Modified Mualem	-0.225
AX Farm Backfill	Modified Mualem	-0.683	Modified Mualem	0.375

*The pore scale parameter is also known as the tortuosity-connectivity coefficient, and the Subsurface Transport Over Multiple Phases (STOMP, developed and distributed by Battelle Memorial Institute) default value of 0.5 is applied to all of the aquifer hydrostratigraphic units.

Source: Section 3.1.4.4 of RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*.

H1 = Hanford formation unit 1 H2 = Hanford formation unit 2 H3 = Hanford formation unit 3

1

4.3.3 Boundary Conditions

Boundary conditions impose conditions or fluxes across grid-cell surfaces that are not coupled to an adjacent active grid cell via the Boundary Conditions Card (~Boundary Conditions Card). The WMA A-AX PA model includes both Dirichlet-type and Neumann-type aqueous boundary conditions. The orientation of the six surfaces of each grid cell in the computational coordinate system define the external grid-cell surface of the boundary. In the rotated model coordinate system, “west” and “east” denote the planes normal to the X-direction (geographically from northwest to southeast), “south” and “north” denote the planes normal to the Y-direction (geographically from southwest to northeast), and “bottom” and “top” denote the planes normal to the Z-direction. Any external boundary surfaces without specified boundary conditions default to zero flux boundaries for both aqueous flow and solute transport. No boundary conditions are specified for the bottom of the model domain during any of the modeling stages (Section 3.4.1), which indicates that the boundary condition defaults to zero flux for aqueous flow and solute transport.

The Dirichlet-type aqueous boundary conditions in the WMA A-AX PA model impose pressures at the centroid of east-face external grid-cell surfaces that represent the aquifer, including the model layer immediately about the water table, to approximate the 119.5 m NAVD88 water table elevation in the aquifer (Section 3.1.7 and Section C.3 of Appendix C of RPP-RPT-60101). The Dirichlet-type “seepage face” boundary condition allows aqueous flow to exit the external grid-cell surface when the aqueous phase pressure exceeds the local gas pressure (PNNL-12030). As indicated in Table 4-8, the pressure necessary to produce 119.495937[6] m NAVD88 (the water table elevation at the east face external surface) along the east face external surface in the bottommost active layer of the model is 217583.25 Pa. The seepage face boundary condition is declared only for the nodes at the lowest elevation in a vertical column. STOMP calculates the pressure in the other layers declared in the boundary condition internally using a vertical hydrostatic gradient (PNNL-12030). The remaining boundary surfaces of the vadose zone along this face involve no declared boundary conditions, which indicates that the boundary condition defaults to zero flux for aqueous flow.

During the first steady-state preconditioning stage, the boundary conditions of the north and south face external grid-cell surfaces representing the aquifer and vadose zone are undeclared and therefore zero flux. After that stage, the aquifer boundary conditions, including the model layer immediately about the water table, become “initial condition,” which is a Dirichlet-type boundary condition. Initial condition indicates that the aqueous pressure imposed at the external surface is equal to the beginning pressure of the node associated with the cell surface. The remaining boundary surfaces of the vadose zone along this face involve no declared boundary conditions, which indicates that the boundary condition defaults to zero flux for aqueous flow. Because the second steady-state preconditioning stage, the operations period, and the post-closure period involve restarts from antecedent simulations, the restart file contains the aqueous pressure values that become the initial condition boundary conditions.

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[6] The precision expressed in the value does not denote confidence in the quantitative estimates of the real-world system to the indicated level of accuracy, but describes the precision necessary to verify the calculation.

Table 4-8. Boundary Conditions of the First Steady-State Preconditioning Stage of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model.

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
1	file	tank_farm_a_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
2	file	tank_farm_an_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
3	file	tank_farm_ap_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
4	file	tank_farm_aw_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
5	file	tank_farm_ax_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
6	file	tank_farm_az_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
7	file	wma_aax_disturbed_01.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
8	file	wma_aax_disturbed_02.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
9	file	wma_aax_disturbed_03.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
10	file	wma_aax_resurfaced_01.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
11	file	wma_aax_resurfaced_02.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
12	file	wma_aax_resurfaced_03.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
13	file	westaquifer_ccg.lst	neumann	N/A	1	1	0	year	0.139E+00	m/d
14	file	westaquifer_rua.lst	neumann	N/A	1	1	0	year	0.764E-05	m/d
15	east	N/A	seepage face	100,100,1,120, 6,19	1	1	0	year	217583.25	Pa

East boundary water table elevation = 119.495937 m (see note in Table 4-3).
Elevation of bottommost active layer (K=6) = 95.25 m +3 m+2.5 m+2.25 m+2 m+1.75 m + (1.75 m)/2 = 107.625 m (Table 4-1, Z-Direction Grid Cells, k =1 to 6)
101325 Pa + (119.495937 m – 107.625 m * 9793.52 Pa/m = 217583.25 Pa.

N/A = not applicable

Neumann-type boundary conditions impose specified aqueous fluxes through the west-face external grid-cell surfaces that represent the aquifer to approximate the estimated flow of 1,052 m^3/day (Section 3.1.1 and Section C.6 of Appendix C of RPP-RPT-60101) through the aquifer. As indicated in Section C.6 of Appendix C of RPP-RPT-60101, the flow is divided between the two aquifer HSUs present at the west-face of the model domain. Assuming that the hydraulic gradient in the aquifer is the same in the Cold Creek gravel and Ringold Unit A, the flux equals 0.139 m/d and 7.64×10^{-6} m/d for the two HSUs, respectively (Section C.7 of Appendix C of RPP-RPT-60101). The boundary surfaces of the vadose zone along this face involve no declared boundary conditions, which indicates that the boundary condition defaults to zero flux for aqueous flow.

Neumann-type boundary conditions also impose specified aqueous fluxes through the top-face external area of grid-cell surfaces that represent ground surface in the model to approximate the net infiltration that becomes recharge (Section 3.1.5 of RPP-RPT-60101). These boundary conditions vary in both time and space because of changes that have occurred or are assumed to occur to the ground surface. During the preconditioning stages before any surface disturbances occur, the net infiltration remains a uniform 3.5 mm/yr (Table 4-8 and Table 4-9). When surfaces become disturbed during the operations period, the net infiltration increases to either 63 mm/yr or 100 mm/yr, depending on whether the surface was just disturbed or became a tank farm. Certain areas became disturbed prior to becoming a tank farm. In these areas, the net infiltration increases to 63 mm/yr when the surface became disturbed, and then to 100 mm/yr when the surface became a tank farm (Table 4-10). The changes in net infiltration occur as step changes.

During the post-closure period that is assumed to begin in 2050, the surface conditions vary in one of two ways (Table 4-11). The tank farm surfaces are assumed to receive a barrier in 2050, and the surrounding disturbed surfaces are assumed to undergo revegetation in 2080. For surfaces that receive a barrier, the net infiltration decreases to 0.5 mm/yr for 500 years, and then increases to 3.5 mm/yr for the duration of the simulation. The changes in net infiltration at the tank farms occur as step changes. For the surrounding surfaces that undergo revegetation, revegetation is assumed to begin 30 years after tank farm closure, i.e., not until 2080. The net infiltration decreases to 3.5 mm/yr, but the decrease occurs linearly from the disturbed rate of 63 mm/yr to 3.5 mm/yr during the 30 years it is assumed that revegetation requires.

The solute boundary conditions for all boundaries except the zero flux boundaries in the vadose zone and along the bottom of the model domain involve the Dirichlet-type called “outflow” in the STOMP user guide (PNNL-12030, which is also applicable to eSTOMP). The outflow boundary condition dictates that solute transport out of the domain only occurs via aqueous phase advection in the direction of the boundary-surface normal and ignores diffusive transport.

4.3.4 Radionuclide Transport Properties

Input cards that describe and quantify the radionuclide transport properties include the Solute/Fluid Interaction Card (~Solute/Fluid Interaction Card) and the Solute/Porous Media Interaction Card (~Solute/Porous Media Interaction Card). Solute/fluid interaction involves identifying how diffusion through the fluid is calculated, and how solutes partition between the solid and aqueous phases (Table 4-12). The conventional diffusion option in STOMP includes the moisture content in the calculation of the cross-sectional area available for diffusion in the unsaturated media. In saturated media, the cross-sectional area available for diffusion equals the effective porosity. The molecular diffusion coefficient represents solute diffusion through the fluid, independent of the porous media. The continuous solid/aqueous partition option assumes that the solid surface is continuously wet independent of the aqueous saturation. The solute/fluid interaction card also includes the entry for radionuclide half-life for radioactive contaminants.

Solute/porous media interaction involves solid-aqueous phase partitioning and hydraulic dispersion in the porous media. Solid-aqueous partitioning coefficients describe the interface equilibrium of the solute adsorbed on the solid material relative to that dissolved in the aqueous phase. The partitioning coefficient (referred to as the K_d) represents the ratio of the equilibrium concentration of solute adsorbed on the solid phase (per unit mass of solid phase material) to the concentration of solute dissolved in the aqueous phase (per unit volume of the aqueous phase) (PNNL-12030). K_d values depend on the solute, HSU, and the gravel content (Table 4-13). The K_d values shown in Table 4-13 include gravel correction, as discussed in Section 3.1.6.2 in RPP-RPT-60101 and summarized in Table 3-8 in RPP-RPT-60101.

In STOMP, the three directional components of the hydrodynamic dispersion tensor are computed using the three Darcy velocity flux components and the longitudinal and transverse hydraulic dispersivity values (PNNL-12030). Longitudinal and transverse hydraulic dispersivity are properties of the individual HSUs (Table 4-13).

4.3.5 Radionuclide Source and Release

RPP-RPT-60885 and RPP-CALC-62319 include the description and development of the release functions that represent and approximate the quantities of the radionuclides and non-radiological contaminants released from the tanks and ancillary equipment, including pipelines. The spreadsheet named "GoldSim_A-AX_Release_Curves_Tc99_I129_U238_20181220.xlsx" includes the time series of releases of ^{99}Tc and ^{129}I that occur from each source (RPP-RPT-60885). For use in the STOMP process model, the values contained in the spreadsheet and presented in the figures must be divided by the number of nodes associated with each source: 32 nodes for 100-series tanks, 539 for the A Farm ancillary equipment and pipelines, and 323 nodes for the AX Farm ancillary equipment and pipelines. Release rates less than zero at some timesteps in the spreadsheet are set equal to zero in the STOMP input. Appendix A includes the listing of source nodes associated with each source, and the number of time steps associated with each release. Figure 4-1 and Figure 4-2 show source release functions and cumulative amount released for ^{99}Tc and ^{129}I, respectively.

Table 4-9. Boundary Conditions of the Second Steady-State Preconditioning Stage of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
1	file	tank_farm_a_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
2	file	tank_farm_an_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
3	file	tank_farm_ap_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
4	file	tank_farm_aw_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
5	file	tank_farm_ax_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
6	file	tank_farm_az_backfill.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
7	file	wma_aax_disturbed_01.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
8	file	wma_aax_disturbed_02.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
9	file	wma_aax_disturbed_03.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
10	file	wma_aax_resurfaced_01.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
11	file	wma_aax_resurfaced_02.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
12	file	wma_aax_resurfaced_03.lst	neumann	N/A	1	1	0	year	-3.5	mm/yr
13	file	westaquifer_ccg.lst	neumann	N/A	1	1	0	year	0.139E+00	m/d
14	file	westaquifer_rua.lst	neumann	N/A	1	1	0	year	0.764E-05	m/d
15	east	N/A	seepage face	100,100,1, 120,6,19	1	1	0	year	217583.25	Pa
16	south	N/A	initial condition	1,100,1,1,6, 19	1	1	0	year	N/A	N/A
17	north	N/A	initial condition	58,100,120, 120,6,6	1	1	0	year	N/A	N/A

Table 4-9. Boundary Conditions of the Second Steady-State Preconditioning Stage of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
18	north	N/A	initial condition	35,100,120, 120,7,7	1	1	0	year	N/A	N/A
19	north	N/A	initial condition	19,100,120, 120,8,8	1	1	0	year	N/A	N/A
20	north	N/A	initial condition	11,100,120, 120,9,9	1	1	0	year	N/A	N/A
21	north	N/A	initial condition	6,100,120, 120,10,10	1	1	0	year	N/A	N/A
22	north	N/A	initial condition	2,100,120, 120,11,11	1	1	0	year	N/A	N/A
23	north	N/A	initial condition	1,100,120, 120,12,19	1	1	0	year	N/A	N/A

N/A = not applicable

Table 4-10. Boundary Conditions of the Operations Period of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (3 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
1	file	tank_farm_a_backfill.lst	neumann	Not applicable (N/A)	4	1	1943	year	-3.5	mm/yr
						2	1954	year	-3.5	mm/yr
						3	1954	year	-100	mm/yr
						4	2050	year	-100	mm/yr
2	file	tank_farm_an_backfill.lst	neumann	N/A	6	1	1943	year	-3.5	mm/yr
						2	1963	year	-3.5	mm/yr
						3	1963	year	-63	mm/yr
						4	1977	year	-63	mm/yr
						5	1977	year	-100	mm/yr
						6	2050	year	-100	mm/yr
3	file	tank_farm_ap_backfill.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1982	year	-3.5	mm/yr
						3	1982	year	-100	mm/yr
						4	2050	year	-100	mm/yr
4	file	tank_farm_aw_backfill.lst	neumann	N/A	6	1	1943	year	-3.5	mm/yr
						2	1953	year	-3.5	mm/yr
						3	1953	year	-63	mm/yr
						4	1976	year	-63	mm/yr
						5	1976	year	-100	mm/yr
						6	2050	year	-100	mm/yr
5	file	tank_farm_ax_backfill.lst	neumann	N/A	6	1	1943	year	-3.5	mm/yr
						2	1954	year	-3.5	mm/yr
						3	1954	year	-63	mm/yr
						4	1963	year	-63	mm/yr
						5	1963	year	-100	mm/yr
						6	2050	year	-100	mm/yr
6	file	tank_farm_az_backfill.lst	neumann	N/A	6	1	1943	year	-3.5	mm/yr
						2	1954	year	-3.5	mm/yr

Table 4-10. Boundary Conditions of the Operations Period of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (3 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
						3	1954	year	-63	mm/yr
						4	1970	year	-63	mm/yr
						5	1970	year	-100	mm/yr
						6	2050	year	-100	mm/yr
7	file	wma_aax_disturbed_01.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1953	year	-3.5	mm/yr
						3	1953	year	-63	mm/yr
						4	2050	year	-63	mm/yr
8	file	wma_aax_disturbed_02.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1954	year	-3.5	mm/yr
						3	1954	year	-63	mm/yr
						4	2050	year	-63	mm/yr
9	file	wma_aax_disturbed_03.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1977	year	-3.5	mm/yr
						3	1977	year	-63	mm/yr
						4	2050	year	-63	mm/yr
10	file	wma_aax_resurfaced_01.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1953	year	-3.5	mm/yr
						3	1953	year	-63	mm/yr
						4	2050	year	-63	mm/yr
11	file	wma_aax_resurfaced_02.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1953	year	-3.5	mm/yr
						3	1953	year	-63	mm/yr
						4	2050	year	-63	mm/yr
12	file	wma_aax_resurfaced_03.lst	neumann	N/A	4	1	1943	year	-3.5	mm/yr
						2	1982	year	-3.5	mm/yr
						3	1982	year	-63	mm/yr
						4	2050	year	-63	mm/yr

Table 4-10. Boundary Conditions of the Operations Period of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (3 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
13	file	westaquifer_ccg.lst	neumann	N/A	1	1	1943	year	0.139	m/d
14	file	westaquifer_rua.lst	neumann	N/A	1	1	1943	year	7.64E-06	m/d
15	east	N/A	seepage face	100,100,1, 120,6,19	1	1	1943	year	217583.25	Pa
16	south	N/A	initial condition	1,100,1,1,6, 19	1	1	1943	year	N/A	N/A
17	north	N/A	initial condition	58,100,120, 120,6,6	1	1	1943	year	N/A	N/A
18	north	N/A	initial condition	35,100,120, 120,7,7	1	1	1943	year	N/A	N/A
19	north	N/A	initial condition	19,100,120, 120,8,8	1	1	1943	year	N/A	N/A
20	north	N/A	initial condition	11,100,120, 120,9,9	1	1	1943	year	N/A	N/A
21	north	N/A	initial condition	6,100,120, 120,10,10	1	1	1943	year	N/A	N/A
22	north	N/A	initial condition	2,100,120, 120,11,11	1	1	1943	year	N/A	N/A
23	north	N/A	initial condition	1,100,120, 120,12,19	1	1	1943	year	N/A	N/A

Table 4-11. Boundary Conditions of the Post-Closure Period of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (1 of 2 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	Solute Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
1	file	tank_farm_a_backfill.lst	neumann	outflow	Not applicable (N/A)	4	1	2050	year	-0.5	mm/yr
							2	2550	year	-0.5	mm/yr
							3	2550	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
2	file	tank_farm_an_backfill.lst	neumann	outflow	N/A	4	1	2050	year	-0.5	mm/yr
							2	2550	year	-0.5	mm/yr
							3	2550	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
3	file	tank_farm_ap_backfill.lst	neumann	outflow	N/A	4	1	2050	year	-0.5	mm/yr
							2	2550	year	-0.5	mm/yr
							3	2550	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
4	file	tank_farm_aw_backfill.lst	neumann	outflow	N/A	4	1	2050	year	-0.5	mm/yr
							2	2550	year	-0.5	mm/yr
							3	2550	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
5	file	tank_farm_ax_backfill.lst	neumann	outflow	N/A	4	1	2050	year	-0.5	mm/yr
							2	2550	year	-0.5	mm/yr
							3	2550	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
6	file	tank_farm_az_backfill.lst	neumann	outflow	N/A	4	1	2050	year	-0.5	mm/yr
							2	2550	year	-0.5	mm/yr
							3	2550	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
7	file	wma_aax_disturbed_01.lst	neumann	outflow	N/A	4	1	2050	year	-63	mm/yr
							2	2080	year	-63	mm/yr
							3	2110	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
8	file	wma_aax_disturbed_02.lst	neumann	outflow	N/A	4	1	2050	year	-63	mm/yr
							2	2080	year	-63	mm/yr
							3	2110	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr

Table 4-11. Boundary Conditions of the Post-Closure Period of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 of 2 sheets)

Boundary Condition Number	External File or Surface Orientation Keyword	External File Name	Aqueous Boundary Condition Option	Solute Boundary Condition Option	I, J, K Index Start and End	Number of Time Periods	Time Period	Time	Time Units	Boundary Condition Value	Boundary Condition Units
9	file	wma_aax_disturbed_03.lst	neumann	outflow	N/A	4	1	2050	year	-63	mm/yr
							2	2080	year	-63	mm/yr
							3	2110	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
10	file	wma_aax_resurfaced_01.lst	neumann	outflow	N/A	4	1	2050	year	-63	mm/yr
							2	2080	year	-63	mm/yr
							3	2110	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
11	file	wma_aax_resurfaced_02.lst	neumann	outflow	N/A	4	1	2050	year	-63	mm/yr
							2	2080	year	-63	mm/yr
							3	2110	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
12	file	wma_aax_resurfaced_03.lst	neumann	outflow	N/A	4	1	2050	year	-63	mm/yr
							2	2080	year	-63	mm/yr
							3	2110	year	-3.5	mm/yr
							4	12050	year	-3.5	mm/yr
13	file	westaquifer_ccg.lst	neumann	outflow	N/A	1	1	2050	year	0.139	m/d
14	file	westaquifer_rua.lst	neumann	outflow	N/A	1	1	2050	year	7.64E-06	m/d
15	east	N/A	seepage face	outflow	100,100,1,120,6,19	1	1	2,050	year	217583.25	Pa
16	south	N/A	initial condition	outflow	1,100,1,1,6,19	1	1	2050	year	N/A	N/A
17	north	N/A	initial condition	outflow	58,100,120,120,6,6	1	1	2050	year	N/A	N/A
18	north	N/A	initial condition	outflow	35,100,120,120,7,7	1	1	2050	year	N/A	N/A
19	north	N/A	initial condition	outflow	19,100,120,120,8,8	1	1	2050	year	N/A	N/A
20	north	N/A	initial condition	outflow	11,100,120,120,9,9	1	1	2050	year	N/A	N/A
21	north	N/A	initial condition	outflow	6,100,120,120,10,10	1	1	2050	year	N/A	N/A
22	north	N/A	initial condition	outflow	2,100,120,120,11,11	1	1	2050	year	N/A	N/A
23	north	N/A	initial condition	outflow	1,100,120,120,12,19	1	1	2050	year	N/A	N/A

Table 4-12. Radionuclide Solute Fluid Transport Properties of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model.

Radionuclide	Effective Diffusion Option	Aqueous-Phase Molecular Diffusion Coefficient	Aqueous-Phase Molecular Diffusion Coefficient Units	Solid/ Aqueous Partition Option	Radionuclide Half-Life	Radionuclide Half-Life Units
Technetium-99	Conventional	0.25E-04	cm^2/s	Continuous	0.2111E+06	Years
Iodine-129	Conventional	0.25E-04	cm^2/s	Continuous	1.57E+07	Years

Source: Section 3.1.4.5.3 and Section 3.1.6 in RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis* (or "ICRP Publication 107: Nuclear Decay Data for Dosimetric Calculations" [ICRP 2008]).

The number of source location declarations associated with the ancillary equipment and pipelines required that the releases of ^{99}Tc and ^{129}I be truncated to satisfy the 200,000-line file size limitation of STOMP. The release functions calculated in the system model (RPP-RPT-60885) have 1-year time steps from 0 to 1,000 years, and 10-year time steps thereafter. The releases are truncated according to the following steps.

1. Negative release rates in the system model release functions are zeroed out.

2. The incremental release rates are integrated { (time[2] - time[1])×0.5×(release[2] + release[1]) } and summed to calculate the total released during 10,000 years.

3. The release rates while the integrated total is < 0.9999 of the total released according to step 2 remain unchanged.

4. The release rate of the time step identified after the total released is ≥ 0.9999 of the total also remains unchanged. This is the final release rate.

5. The incremental release rates of steps 3 and 4 are integrated and summed.

6. The difference between the total inventory released (step 2) and the ~0.9999 of the inventory released (step 5) is calculated.

7. The difference calculated in step 6 is divided by the final release rate of the time step identified in step 4 to calculate a duration. This number is rounded to the nearest time step.

8. The final release rate, identified in step 4, with a duration equal to the time calculated in step 7, is repeated and appended to the release rates of steps 3 and 4.

Table 4-13. Radionuclide Solute Porous Media Transport Properties of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 sheets)

Hydrostratigraphic Unit	Longitudinal Dispersivity	Longitudinal Dispersivity Units	Transverse Dispersivity	Transverse Dispersivity Units	Contaminant or Radionuclide	Solid-Aqueous Partition Coefficient	Solid-Aqueous Partition Coefficient Units
Eolian	25	cm	2.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.19	mL/g
A Farm Backfill	15	cm	1.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.084	mL/g
AX Farm Backfill	25	cm	2.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.186	mL/g
H1 Gravelly Sand	25	cm	2.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.19	mL/g
H2 Sand	25	cm	2.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.19	mL/g
H3 Gravelly Sand Vadose	15	cm	1.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Cold Creek Silt Vadose	5	cm	0.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.2	mL/g
Cold Creek Gravel Vadose	15	cm	1.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Ringold E Vadose	15	cm	1.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Ringold LM Vadose	5	cm	0.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.2	mL/g

Table 4-13. Radionuclide Solute Porous Media Transport Properties of the Three-Dimensional Waste Management Area A-AX Flow and Transport Model. (2 sheets)

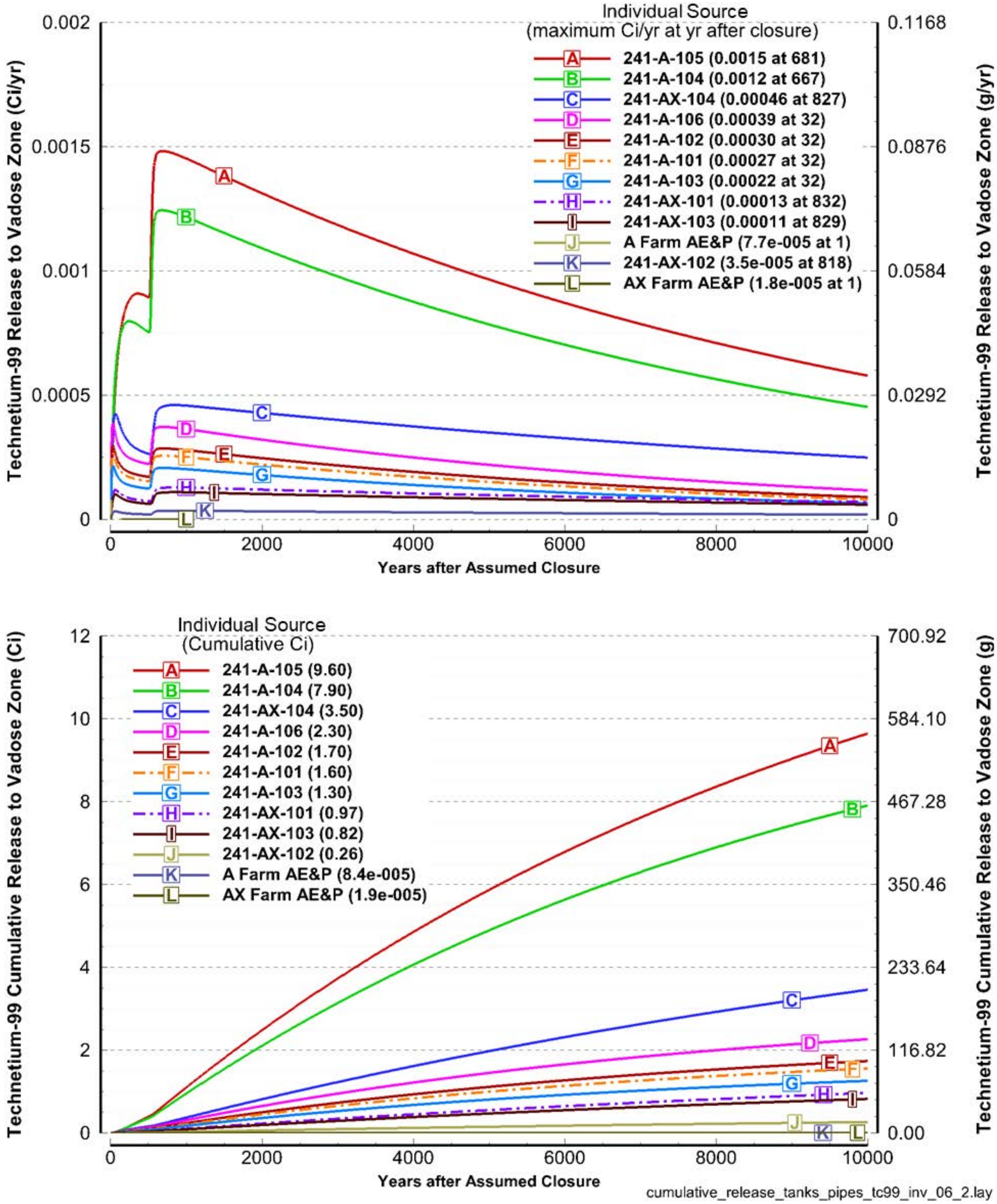
Hydrostratigraphic Unit	Longitudinal Dispersivity	Longitudinal Dispersivity Units	Transverse Dispersivity	Transverse Dispersivity Units	Contaminant or Radionuclide	Solid-Aqueous Partition Coefficient	Solid-Aqueous Partition Coefficient Units
Ringold A Vadose	15	cm	1.5	cm	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Cold Creek Gravel Aquifer	10.5	m	1.05	m	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Ringold E Aquifer	10.5	m	1.05	m	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Ringold LM Aquifer	10.5	m	1.05	m	Technetium-99	0	mL/g
					Iodine-129	0.2	mL/g
Ringold A Aquifer	10.5	m	1.05	m	Technetium-99	0	mL/g
					Iodine-129	0.068	mL/g
Basalt*	10.5	m	1.05	m	Technetium-99	0	mL/g
					Iodine-129	0	mL/g

Sources: Longitudinal and transverse dispersivity values in Table 3-4 in Section 3.1.4.5.1 and Table 3-9 in Section 3.1.7 of RPP-RPT-60101, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*; solid-aqueous partition coefficient values in Table 3-8 in Section 3.1.6.2 of RPP-RPT-60101. Iodine-129 values may be rounded to two decimal places in input files.

H1 = Hanford formation unit 1 H2 = Hanford formation unit 2 H3 = Hanford formation unit 3

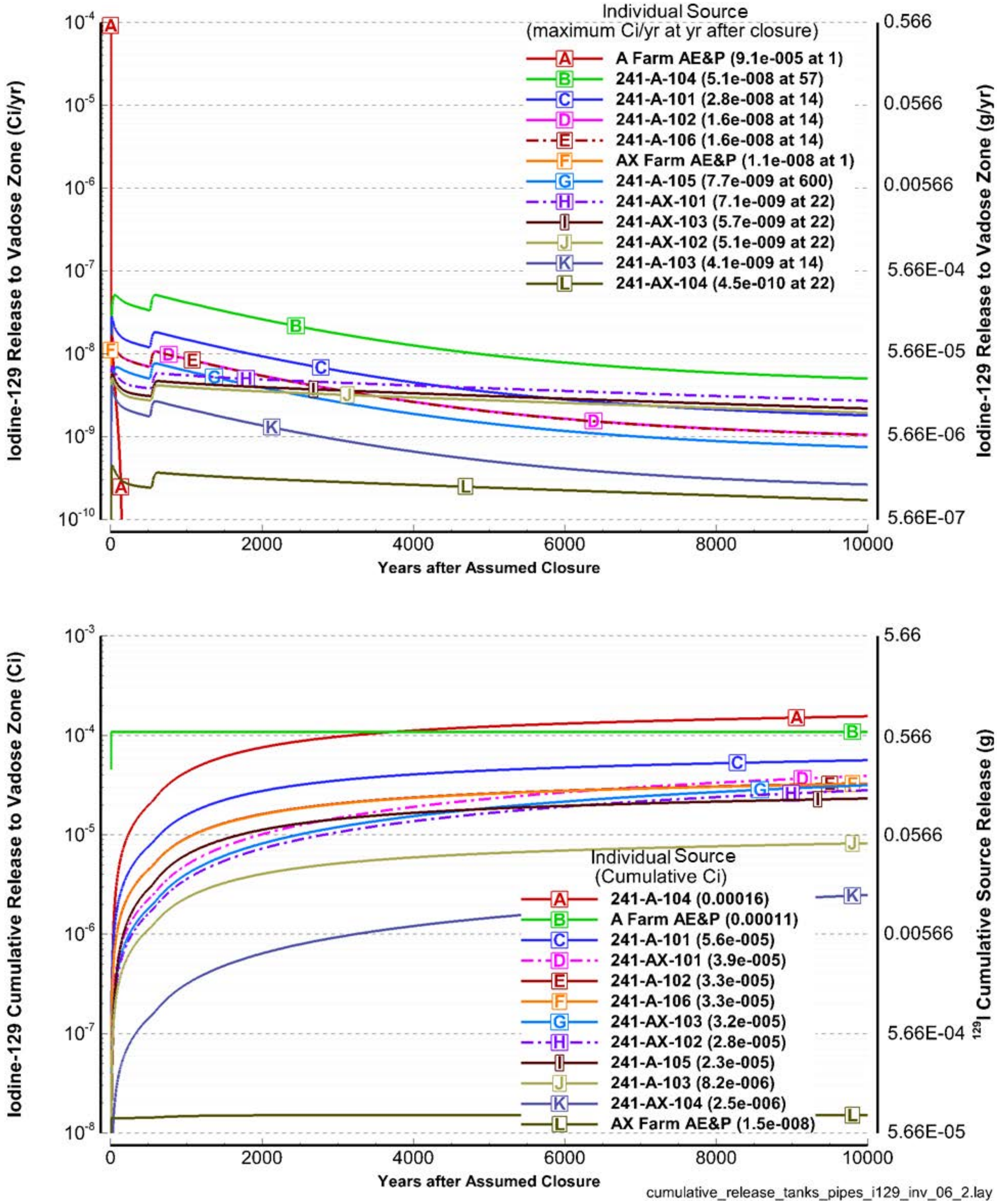
*Basalt cells are inactive in the model domain and the assumed basalt parameters do not affect the simulations (see note b in Table 4-2).

Figure 4-1. Technetium-99 Source Release Functions and Cumulative Amount Released during the 10,000-year Process Model Simulation Period.



AE&P = ancillary equipment and pipelines

Figure 4-2. Iodine-129 Source Release Functions and Cumulative Amount Released during the 10,000-year Process Model Simulation Period.



AE&P = ancillary equipment and pipelines

4.4 MODEL EVALUATION CASE INPUTS

The process model evaluation case inputs are identical to the model inputs previously discussed, except for the Courant number numerical dispersion and PETSc solver tests. The mass balance evaluation and the comparison of simulated vadose zone moisture content to WMA A-AX field-measured data involve the previously discussed input. The numerical dispersion and solver tests involve modifications to those criteria and the evaluation of ^{99}Tc releases from tanks 241-A-102 and 241-AX-101, which the system modeling identifies as representative tanks and vadose zone column locations for the system model abstraction (RPP-RPT-60885). The numerical dispersion tests for Courant number limits of 1 and 10 are shortened to simulate 3,000 years from 2050 to 5050 to avoid excessive run times.

The Courant numerical dispersion evaluation includes Courant numbers of 1, 10, and 25:

```
~Solution Control Card
restart file w/petsc, ./restart, 1.0E-12, 1.0E-25,
Water w/ Transport w/ Courant, 1.,
```

and

```
~Solution Control Card
restart file w/petsc, ./restart, 1.0E-12, 1.0E-25,
Water w/ Transport w/ Courant, 10.,
```

The convergence criteria test involves the eSTOMP PETSc solver evaluated with the relative convergence tolerance equal to 1.0000E-12 and the absolution convergence tolerance equal to 1.0000E-25 compared to the serial STOMP bi-conjugate gradient stabilized solver with the default maximum convergence residual = 1.0000E-06:

```
~Solution Control Card
restart file w/petsc, ./restart, 1.0E-12, 1.0E-25,
Water w/ Transport w/ Courant, 25.,
```

and

```
~Solution Control Card
restart,,
Water w/ Transport w/ Courant, 25.,
```

Use of the default maximum convergence residual does not require specification in the serial STOMP input file.

5 SOFTWARE APPLICATIONS

The Subsurface Transport Over Multiple Phases Software (both STOMP and eSTOMP) software is licensed by CHPRC for use under the terms of a limited government license from Pacific Northwest National Laboratory (PNNL), which developed the code to meet American Society of Mechanical Engineers (ASME) NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications* and DOE O 414.1C, *Quality Assurance* software requirements when those were applicable orders and standards. Currently, PNNL manages STOMP and eSTOMP under Configuration Management Plans (PNNL-SA-92584, *Subsurface Transport Over Multiple Phases (STOMP) Software Configuration Management Plan* and PNNL-24121, *eSTOMP Configuration Management Plan*, respectively) in conjunction with Software Test Plans (PNNL-SA-92579 *STOMP Software Test Plan* and PNNL-24120, *eSTOMP Software Test Plan*, respectively), that detail the procedures used to test, document and archive modifications to the source code. PNNL maintains specific operational modes of STOMP and eSTOMP as qualified Safety Software, Level C, per the DOE O 414.1D, *Quality Assurance* definition for safety software and ASME NQA-1-2008 *Quality Assurance Requirements for Nuclear Facility Applications* with NQA-1a-2009 addenda (PNNL-24118, *STOMP/eSTOMP Software Quality Assurance Plan*).

STOMP and eSTOMP (PNNL-11216, PNNL-12030, PNNL-15782) have been selected to simulate the transport of contaminants in the vadose zone and groundwater of the 200 Area in and around WMA A-AX because STOMP and eSTOMP fulfill the following specifications (in the following list STOMP refers to both STOMP and eSTOMP):

- The STOMP simulator solves the necessary governing equations (i.e., Richards' equation and conservation of mass)

- It is capable of directly simulating the principal features, events, and processes (FEPs) that are relevant (see Section 3.1 of RPP-RPT-60101)

- The STOMP simulator is well documented (PNNL-11216, PNNL-12030, PNNL-15782)

- The STOMP simulator development meets ASME NQA-1-2008 with NQA-1a-2009 addenda software requirements and is compliant with DOE O 414.1D requirements for Safety Software (PNNL-SA-92579; PNNL-24120; PNNL-SA-92584; PNNL-24121; PNNL-24122, *Software Requirements Document for STOMP and eSTOMP*)

- The STOMP simulator operational modes needed for implementation of this model are available free for government use under a limited government-use agreement

- The STOMP simulator is distributed with source code, enhancing transparency

- The modeling team implementing this model has expertise in use of this simulator

- There is an extensive history of application of STOMP at Hanford and elsewhere including verification, validation, and benchmarking (DOE/RL-2011-50)

- Use of STOMP is in keeping with DOE direction for simulation of vadose zone flow and transport at the Hanford Site (Letter 06-AMCP-0133, "Contract No. DE-AC06-05RL14655 – Hanford Groundwater Modeling Integration").

Tecplot 360® is a software application developed by Tecplot, Inc. for plotting inputs and results, gridding, and contouring of surfaces and isopleths from regularly and irregularly-spaced discrete point data. Tecplot 360® includes data operations that allow addition or subtraction of multiple data sets to generate the combinations and composites of the volume and time series results discussed in Section 7. Tecplot 360® is used to prepare the time series breakthrough curves and planar view graphics shown in the figures in that section. Use of Tecplot 360®[7] software occurs in accordance with CHPRC procedure PRC-PRO-IRM-309, "Controlled Software Management" for level "N/A" software. Tecplot 360® is graded Level "N/A" software and therefore has reduced quality assurance documentation requirements relative to Level C software such as STOMP.

Microsoft®[8] Excel® 2016 MSO (16.0.4738.1000) 32-bit software is used to build spreadsheets to post-process the model results and perform the groundwater time series concentration and mass balance calculations. Excel® is a "Site Licensed Client Software," and is exempt from formal control requirements of PRC-PRO-IRM-309. The spreadsheets serve as desktop calculators, and are not intended to be reused. Therefore, the requirements of PRC-PRO-IRM-309 do not apply to this application of the software.

5.1 SOFTWARE IDENTIFICATION

The following describes the STOMP and eSTOMP controlled calculation software and its computational platform.

- Software Title: STOMP-W and eSTOMP-W (a scientific tool for analyzing single- and multiple-phase subsurface flow and transport using the integrated finite volume discretization technique with Newton-Raphson iteration).

- Software Version: STOMP-W was provided by PNNL on January 30, 2013, and was tested and approved for use by CHPRC as "CHPRC Build 4." eSTOMP-W was provided by PNNL on May 30, 2017, and was tested and approved for use by CHPRC as "CHPRC Build 6." For STOMP-W, CHPRC Build 4 is identical to CHPRC Build 5 and CHPRC Build 6; the latter were issued in response to development of eSTOMP.

- Hanford Information System Inventory (HISI) Identification Number: 2471 (Safety Software S3, graded Level C).

[7] Tecplot 360® is a registered trademark of Tecplot, Inc., 3535 Factoria Blvd. SE, Bellevue, Washington.
[8] Microsoft and Excel are registered trademarks of the Microsoft Corporation.

- Computational Platform: Tellus Subsurface Modeling Platform (Tellus) hosted by Mission Support Alliance for CHPRC
    - Server Chassis: Dell PowerEdge®[9] M1000e Blade Enclosure
    - Compute Nodes: 16 Dell PowerEdge® M610 Blade Servers
        - Intel® Xeon® X5670 CPU (x2), 6 Cores/CPU, 2.93 GHz, 12MB Cache
        - 96 GB RAM; DDR3; 1333 MHz
        - 10Gbps Ethernet Mezzanine Card – Dual Port – X520DA2 x 2
    - Storage: internal hard drives on management (frontend) server includes 4 SAMSUNG 830 Series MZ-7PC512D/AM 2.5” SATAIII MLC Internal Solid State Drives
    - Operating System and Version
        - Red Hat Enterprise Linux®[10] 5 (Tikanga), Release 5.8
        - Rocks Cluster/Ganglia open source software operating system.
- Approved User: W. J. (Bill) McMahon.

The following describes the Tecplot 360® software and its computational platform.

- Software Title and Version: Tecplot 360® 2013 R1 and 2017 R2
- HISI Identification Number: 3882
- U.S. Department of Energy-owned workstation: Dell Precision Tower5810
    - Intel® Xeon® CPU E5-1650-1650 v3 @ 3.50 GHz, 32.0 GB RAM
    - 64-bit operating system, x64-based processor
    - Windows 10 Enterprise version 1709 OS Build 16299.1146.

5.2 SOFTWARE QUALITY ASSURANCE

The use of STOMP and eSTOMP to implement the WMA A-AX PA model and perform calculations, and the use of Tecplot 360® and Microsoft® Excel® to post-process results, is performed in a manner that satisfies and complies with environmental quality assurance requirements indicated by Title 10, CFR, Part 830, “Nuclear Safety Management” (10 CFR 830) and Subpart A—Quality Assurance Requirements; DOE O 414.1D; and State and Federal environmental regulations. EM-QA-001, *EM Quality Assurance Program (QAP),*

[9] Dell® and PowerEdge® are registered trademarks of Dell Products, Inc.
[10] Linux® is the registered trademark of Linus Torvalds in the U.S. and other countries.

Attachment G – "Software Quality Requirements" and Attachment H – "Model Development, Use, and Validation" list DOE management expectations for compliance, including configuration control, evaluation, implementation, verification and validation, and operation and maintenance.

Quality assurance project planning for STOMP and eSTOMP modeling follows the guidance in EPA/240/R-02/007, *Guidance for Quality Assurance Project Plans for Modeling*, EPA QA/G-5M. Model project planning includes documenting specific model development efforts and applications. It addresses as relevant and important all nine "Group A" elements presented in EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5. The nine elements include problem definition and background, quality objectives and criteria for measurements and data acquisition leading to model inputs and outputs, data validation and usability, references, documentation and records management, special training requirements and certifications for modelers, and assessments and reports to management.

5.3 SOFTWARE INSTALLATION AND CHECKOUT

After receipt of the STOMP and eSTOMP source code from PNNL, CHPRC commits the code to the MKS Integrity™[11] configuration management system that ensures traceability and precludes loss of information. Successful acceptance and installation include confirming that the software is operating correctly by benchmarking results produced on the local computer system to those presented for selected problems from the STOMP Application Guide (PNNL-11216). The CHPRC software owner maintains the configuration-managed copies in MKS Integrity™ and grants access to the executable files to users upon request in accordance with the approved software installation and checkout forms.

Receipt of the current STOMP and eSTOMP source code occurred January 2013 and May 2017, respectively. Testing of CHPRC Build 4 of STOMP on Tellus successfully concluded April 2013. Testing of CHPRC Build 6 of eSTOMP on Tellus successfully concluded October 2018. Approved users are registered in HISI for safety software, which identifies W. J. (Bill) McMahon as an authorized user of STOMP and eSTOMP on the Tellus Platform as of May 6, 2013 and October 1, 2018, respectively.

The software installation and checkout form for STOMP is provided in Attachment 1 to this EMCF. Use of Level D software such as Tecplot 360® does not require inclusion of the Software Checkout and Installation Form (SICO) per the requirements of PRC-PRO-IRM-309.

5.4 STATEMENT OF VALID SOFTWARE APPLICATION

The WMA A-AX PA requires calculations of the potential long-term impact on groundwater of post-retrieval SST waste residuals and waste left in ancillary equipment, including pipelines. STOMP and eSTOMP have been developed for this type of applications, among others, and is used to solve the Richards equation and the Advection-Dispersion equation that govern water flow and solute transport, respectively, under variably saturated conditions in the vadose zone

[11] MKS Integrity is a trademark of MKS, Incorporated.

and groundwater. The WMA A-AX PA implementation of STOMP and eSTOMP to perform calculations satisfies and complies with environmental quality assurance requirements indicated by 10 CFR 830, Subpart A; DOE O 414.1D; and State and Federal environmental regulations. Successful acceptance and installation of Build 4 of STOMP and Build 6 of eSTOMP on Tellus concluded in April 2013 and October 2018, respectively. The HISI for safety software lists W. J. (Bill) McMahon as an authorized user of Build 4 of STOMP and Build 6 of eSTOMP on the Tellus Platform. Tecplot 360® and Microsoft® Excel® provide post-processing capability required for the calculation of results, and the presentation and visualization of the results.

The quality assurance project planning for STOMP and eSTOMP modeling follows the guidance in EPA/240/R-02/007, and the conduct of implementation is shown to comply with DOE management expectations for compliance. Calculations with the WMA A-AX PA model use only NQA-1 qualified options and code within the STOMP-W or eSTOMP-W executables and are thus within the intended range of applications. Therefore, for this application, STOMP and eSTOMP are appropriate software codes to use. Using it to implement the WMA A-AX PA model described in this report is consistent with STOMP's intended use, and its use is shown to comply with applicable quality assurance requirements. The use of Tecplot 360® to prepare figures, and to perform the superposition calculations necessary to prepare figures, in this EMCF complies with the range of grade level D intended uses for the software.

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6 CALCULATION

The STOMP and eSTOMP process model simulations occurred as described in Section 3.4, with the input described in Section 4. The surface files produced by the simulations provide the basis for the groundwater concentration values presented in Section 7.

6.1 DESCRIPTION OF MODEL CHANGES

Certain changes have occurred to the process model since the issuance of RPP-RPT-60101. These changes include the development of the inventory release functions, the addition of three PoCal segments to the north of the ones described in RPP-RPT-60101, and the elimination of the screening analysis. The following sections provide the explanation for the changes.

6.1.1 Source Term Inventory and Release Functions

RPP-RPT-60101 identifies the release functions addressed in that document as hypothetical, and only represent a test case to support development of the process model. RPP-CALC-62319 includes the assumptions and methodology used to estimate the post-retrieval inventory. RPP-RPT-60885 includes the description of the inventory release functions that produced the spreadsheet discussed in Section 4.3.5. This spreadsheet provides the basis for the release functions shown in Figure 4-1 and Figure 4-2. As WMA A-AX proceeds toward closure, the inventory estimates are expected to be updated to address pertinent new information derived from the sampling conducted as part of future site characterization efforts.

6.1.2 Points of Calculation

Section 3.1.8 of RPP-RPT-60101 indicates that there are nine hypothetical calculation planes or segments that zigzag northward along the lines parallel to the WMA A-AX fence line. Preliminary results of the process model indicate that the maximum concentration in the aquifer occurs in PoCal segment 9 for certain sources (e.g., tank 241-AX-103 or the AX Farm ancillary equipment and pipeline source). To ensure that the maximum concentration in the aquifer caused by each of the sources does not occur outside the existing PoCals, the PoCals now include three additional sets of zigzagging subsegments located to the north of segment 9. Consistent with the original segments described in RPP-RPT-60101, the additional segments are ~30 m (98 ft) wide normal to the WMA A-AX fence line. Section 6.4 includes description of all the PoCals, including the length of the subsegments, the length parallel to the WMA A-AX fence line each PoCal represents, and the indices associated with each PoCal subsegment.

6.1.3 Screening

RPP-RPT-60101 indicates that RPP-RPT-60885 is expected to provide the results of the screening analysis that identify the key contaminants of potential concern that require specific detailed evaluation in the three-dimensional (3-D) numerical flow and transport process model. The decision to use the system model to evaluate the base case for the contaminants of potential concern and limit the process model to evaluation of ^{99}Tc and ^{129}I for the purpose of benchmarking the system model results, eliminates the need for the screening analysis. The evaluation conducted with the 3-D numerical flow and transport process model only involves ^{99}Tc and ^{129}I.

6.2 MODEL CONFIGURATION CONTROL

All inputs and outputs needed for the development of WMA A-AX PA process models are committed to the Environmental Model Management Archive (EMMA) to maintain and preserve configuration managed models. Inputs include the input files used in the eSTOMP and STOMP simulations and the auxiliary files called by the input files such as the zonation and boundary node list files. Basis information (that information collected to form the basis for model input parameterization) is also stored in the EMMA for traceability purposes. Use of the eSTOMP and STOMP software for implementing the model described in this report is consistent with its intended use for CHPRC, as indicated in Section 5.4 "Statement of Valid Software Application."

6.3 MODEL CHECKING

Model checking occurs in accordance with the requirement specified on Form A-6007-208, "CHECKER LOG FOR PROCESS MODELS."

6.4 DESCRIPTION OF CALCULATED OUTPUT

eSTOMP and STOMP output consists of screen prints, an output file, plot.n files (where n is the timestep number), and surface files. Screen prints, which are directed to a file, include simulation results for selected variables at selected individual reference nodes during the simulation period. The output file contains an interpreted and reformatted version of the input, and the same simulation results as the screen prints, although the frequency of results and number of significant digits intentionally differ between the two. Plot.n files contain values of geometric parameters (e.g., x, y, and z coordinate position and cell volume) and selected variables for the entire computational domain (both active and inactive nodes) at selected simulation times. Surface files contain the flux (rate) and cumulative total (integral) of mass or volume crossing grid-cell surfaces. In the surface files, the quantities include both water (volume) and solutes (mass) crossing the grid-cell surfaces. The variables specified for the screen prints and output files include aqueous and volumetric concentration; however, the results contained in the surface files must be post-processed outside of STOMP or eSTOMP to calculate the aqueous concentration.

As indicated in Section 3.4.2, post-processing outside STOMP or eSTOMP involves dividing the contaminant flux by the water flux at each PoCal flux plane for each time step to produce the concentration value time series for each PoCal. Post-processing includes superposition to sum the concentrations of all of the sources at each PoCal flux plane to determine the peak concentration and identify the location and time of highest projected concentration from all sources. Post-processing also invokes superposition to sum the concentrations of all of the individual sources at each node at a particular time to determine the spatial distribution of the total concentration in the model domain.

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7 RESULTS AND CONCLUSIONS

The process model analysis evaluates forecasted concentrations in groundwater caused by the release of ^{99}Tc and ^{129}I from the residual waste remaining in WMA A-AX after the assumed closure of the WMA occurs. The evaluation includes the combined and individual source contributions to the concentration in groundwater, identifies the peak concentration, and identifies at which PoCal the peak concentration occurs. Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et. al. 1989) indicates that the PA needs to evaluate the relative risk of each component compared to the entire WMA performance. This extends the evaluation of the groundwater concentrations and radionuclide arrival times to 1,000 years to address the compliance timeframe, and to 10,000 years to address the sensitivity and uncertainty timeframe, per the requirements of DOE O 435.1 and DOE M 435.1-1.

The ^{99}Tc and ^{129}I process model results provide a set of benchmarking results to assist the evaluation of the system model. The system model is expected to provide the base case analysis of all the radioactive constituents, in addition to the required sensitivity and uncertainty evaluations. The ^{99}Tc and ^{129}I process model results provide benchmarking or calibration targets for the development of the system model. Although discussion of the process model results includes a direct comparison to the performance objectives, the comparison is only intended to provide context for the magnitude of the groundwater concentration values.

7.1 RESULTS

The process model analysis evaluates the contribution of individual sources on the peak concentration in groundwater and identifies at which PoCal that peak concentration occurs. This approach was taken specifically to address the need to compare model results with groundwater maximum contaminant levels, identify both the combined or cumulative impact from all of the sources, and the impact of each source individually. As indicated previously, the decision to use the system model to evaluate the base case for the contaminants of potential concern limits the scope and purpose of the process model to evaluation of ^{99}Tc and ^{129}I. The ^{99}Tc and ^{129}I simulations provide benchmark results to assist in the development of the vadose and saturated zone system model abstraction, as discussed in RPP-RPT-60885. Development of the system model abstraction primarily involves the results from the three representative tanks, 241-A-102, 241-A-105, and 241-AX-101. Therefore, discussion of the process model results emphasizes the results associated with the three representative tanks.

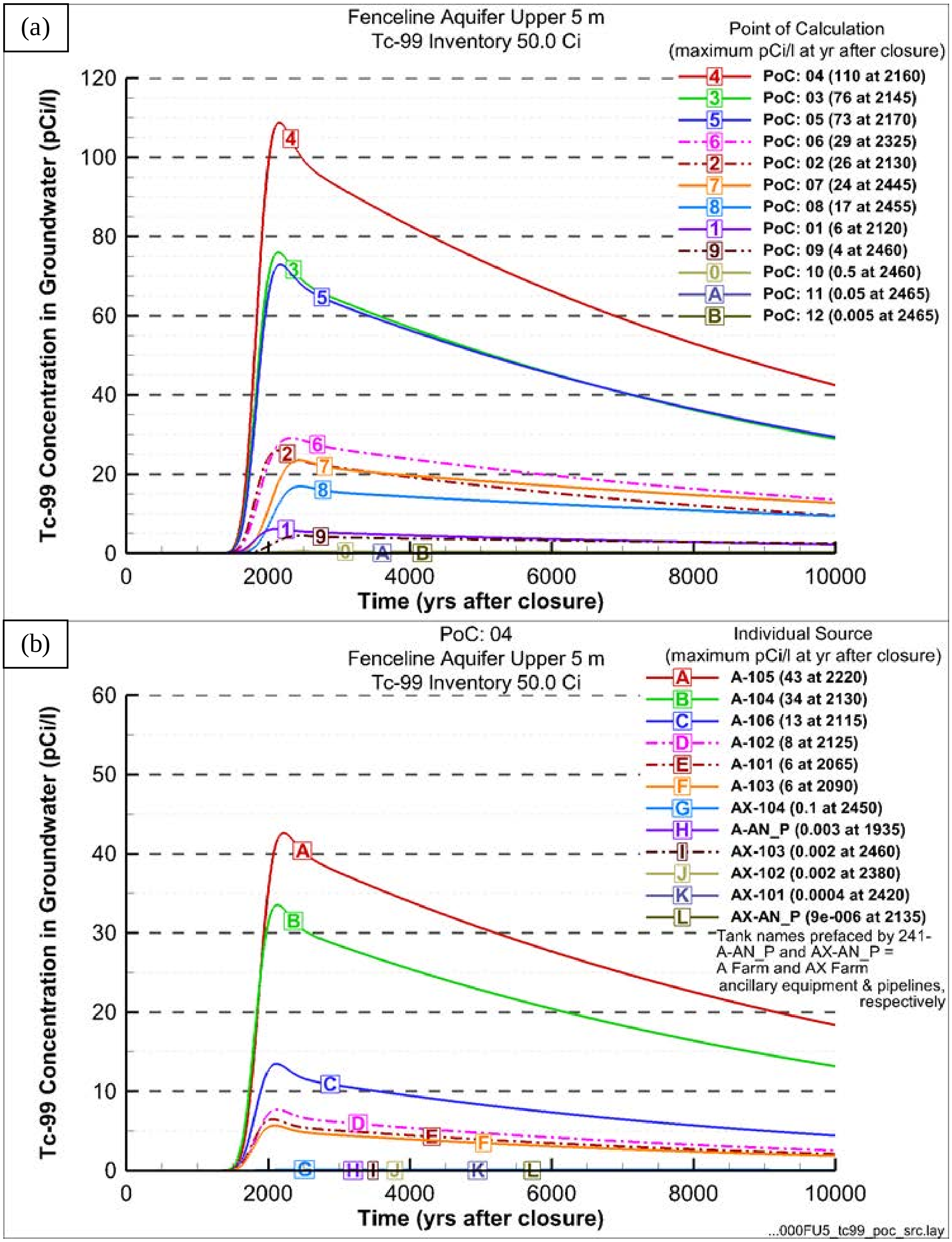
7.1.1 Process Model Results

Figure 7-1 through Figure 7-6 show example breakthrough curves of ^{99}Tc. Figure 7-1 shows the combined or cumulative breakthrough of ^{99}Tc from all the sources at the 12 PoCals along the line of evaluation coincident with the fence line of WMA A-AX, and the contribution from each source identified at the PoCal where the highest concentration occurs. The highest peak concentration occurs within PoCal 4. The ^{99}Tc released from tanks 241-A-105 and 241-A-104 represents the two largest components of that peak concentration. The contribution from each of those two tanks at the time of the peak concentration is more than twice the contribution of any other source. The peak concentration at the PoCal where the maximum concentration occurs is 110 pCi/L, which is almost a factor of 8 less than the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Limit (MCL) of 900 pCi/L (40 CFR 141, Subpart G—National Primary Drinking Water Regulations: Maximum Contaminant Levels and Maximum Residual Disinfectant Levels, § 141.66 Maximum contaminant levels for radionuclides; and EPA 816-F-00-002, *Implementation Guidance for Radionuclides*, pp. I-3). Figure 7-2 shows the breakthrough of ^{99}Tc from the three representative tanks at the 12 PoCals along the fence line of WMA A-AX. Of the three representative tanks identified in Figure 7-2, the forecast residual waste in tank 241-A-105 contains the largest estimated inventory of ^{99}Tc (RPP-CALC-62319), and produces the highest ^{99}Tc concentration in groundwater at PoCal 4. The breakthrough curve at PoCal 3 produced by the estimated residual inventory of ^{99}Tc in tank 241-A-102 peaks about 100 years before the peak associated with tank 241-A-105, even though the tanks are adjacent to one another in A Farm. Although the differences in the hydrostratigraphy between the two tanks are minor, the system model analysis confirms that the arrival times of the peak concentrations occur about 100 years apart (RPP-RPT-60885). The breakthrough curve at PoCal 8 produced by the estimated residual inventory of ^{99}Tc in tank 241-AX-101 peaks about 300 years after the peak associated with tank 241-A-102. Again, even though the tank farms are adjacent to one another, the system model analysis confirms that the arrival times of the peak concentrations occur about 300 years apart (RPP-RPT-60885).

Figure 7-3 shows the combined or cumulative breakthrough of ^{99}Tc from all the sources at the 12 PoCals along the line of evaluation 100 m from WMA A-AX, and the contribution from each source identified at the PoCal where the highest concentration occurs. The highest peak concentration occurs within PoCal 5, and the ^{99}Tc released from tanks 241-A-105 and 241-A-104 remains the two largest components of that peak concentration. The contribution from each of those two tanks at this distance from WMA A-AX at the time of the peak concentration is more than three times the contribution of any other source. The peak concentration at the PoCal where the maximum concentration occurs is 77 pCi/L, which is almost a factor of 12 less than the EPA MCL. Figure 7-4 shows the breakthrough of ^{99}Tc from the three representative tanks at the 12 PoCals 100 m from WMA A-AX. The breakthrough curves shown in Figure 7-4 are similar to those shown in Figure 7-2, but the magnitude of the groundwater concentration values decreases because of the additional 100 m of transport through the aquifer. The arrival times of the peak concentration at the PoCals 100 m from WMA A-AX are essentially identical to those that occur at the WMA A-AX fence line, which is consistent with groundwater flow velocities higher than 100 m/yr as discussed in Appendix C of RPP-RPT-60101.

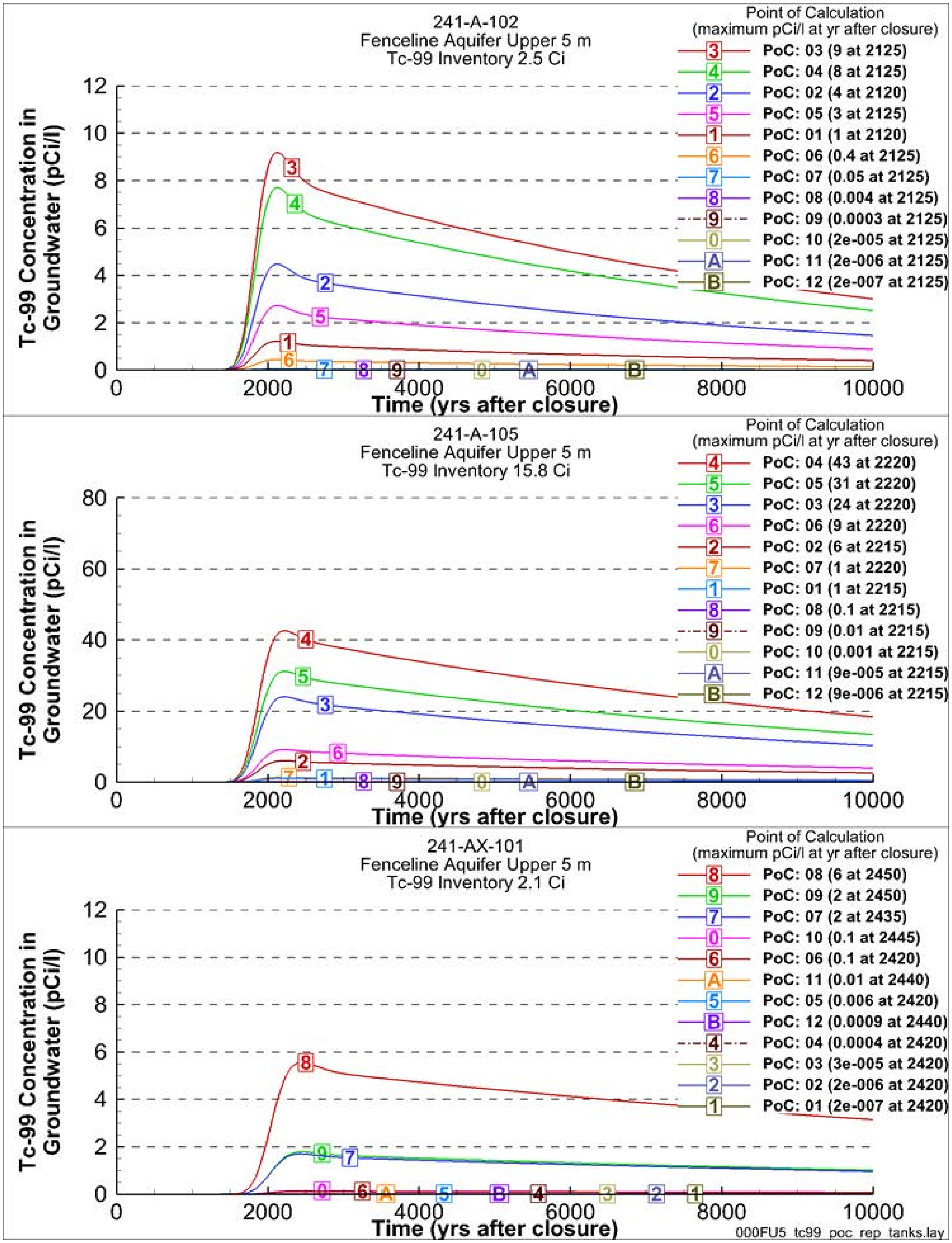
Figure 7-5 shows the combined or cumulative breakthrough of ^{99}Tc from all the sources at the 12 PoCals along the line of evaluation 200 m from WMA A-AX, and the contribution from each source identified at the PoCal where the highest concentration occurs. The highest peak concentration still occurs within PoCal 5, but the peak concentration within PoCal 6 is almost as large. The ^{99}Tc released from tanks 241-A-105 and 241-A-104 remains the two largest components of that peak concentration and remains about three times the contribution of any other source. The peak concentration at the PoCal where the maximum concentration occurs is 66 pCi/L, which is almost a factor of 14 less than the EPA MCL.

Figure 7-1. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration at the Waste Management Area A-AX Fence Line (a) for the Groundwater Points of Calculation and (b) for the Individual Components at the Point of Calculation Where the Maximum Concentration Occurs.



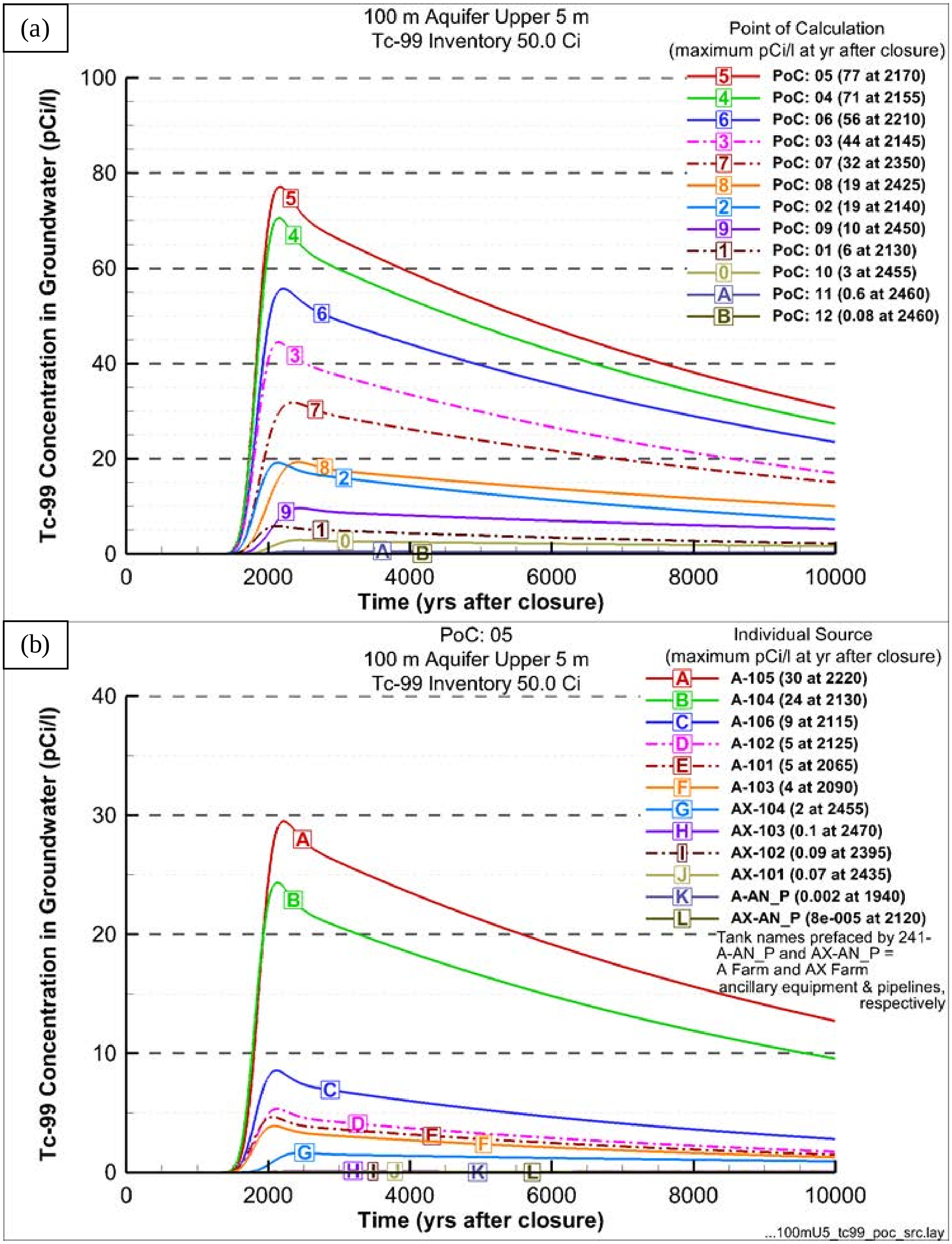
WMA = Waste Management Area

Figure 7-2. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentrations at the Fence Line Groundwater Points of Calculation for the Representative Tanks Identified in RPP-RPT-60885.



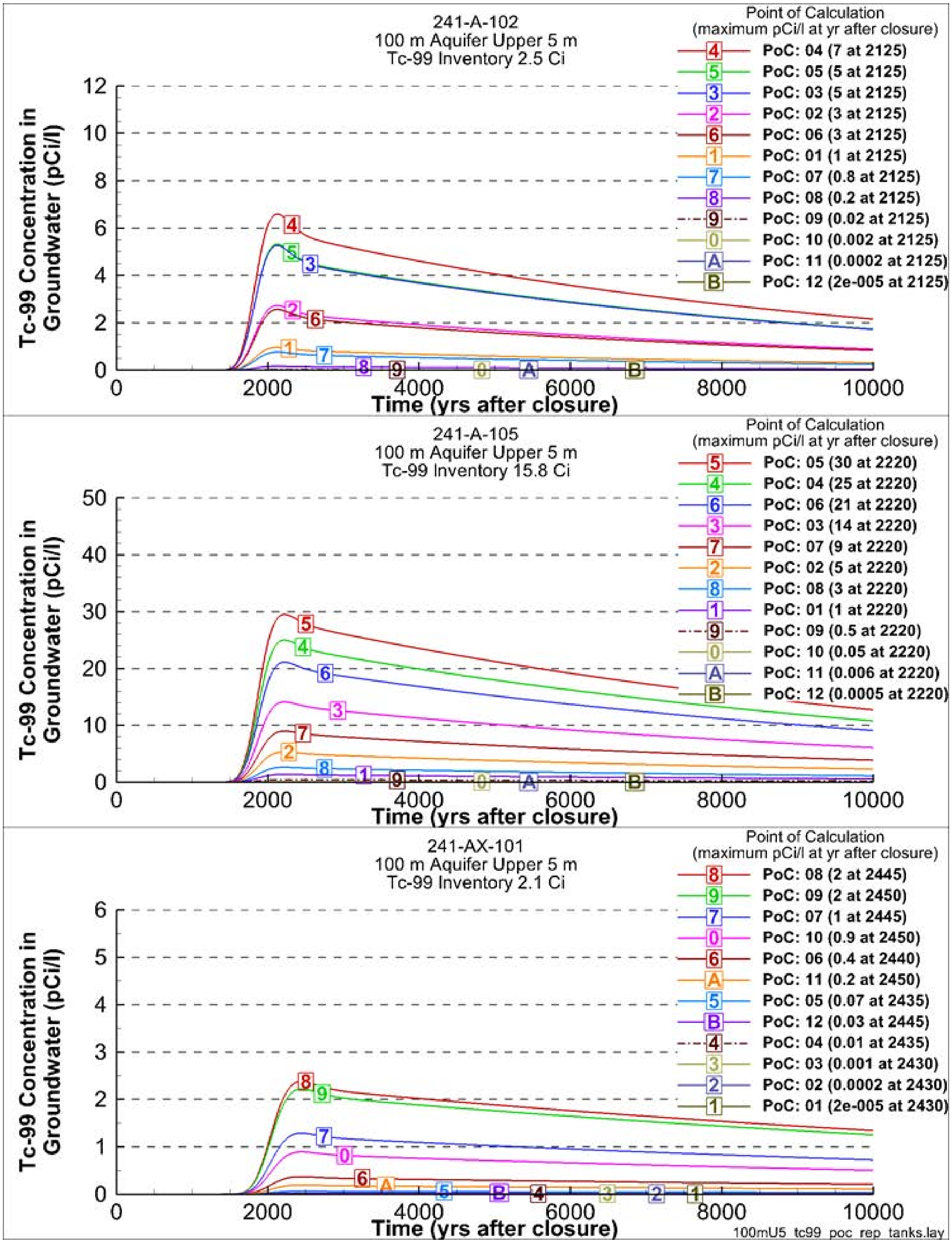
Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-3. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration 100 meters from Waste Management Area A-AX (a) for the Groundwater Points of Calculation and (b) for the Individual Components at the Point of Calculation Where the Maximum Concentration Occurs.



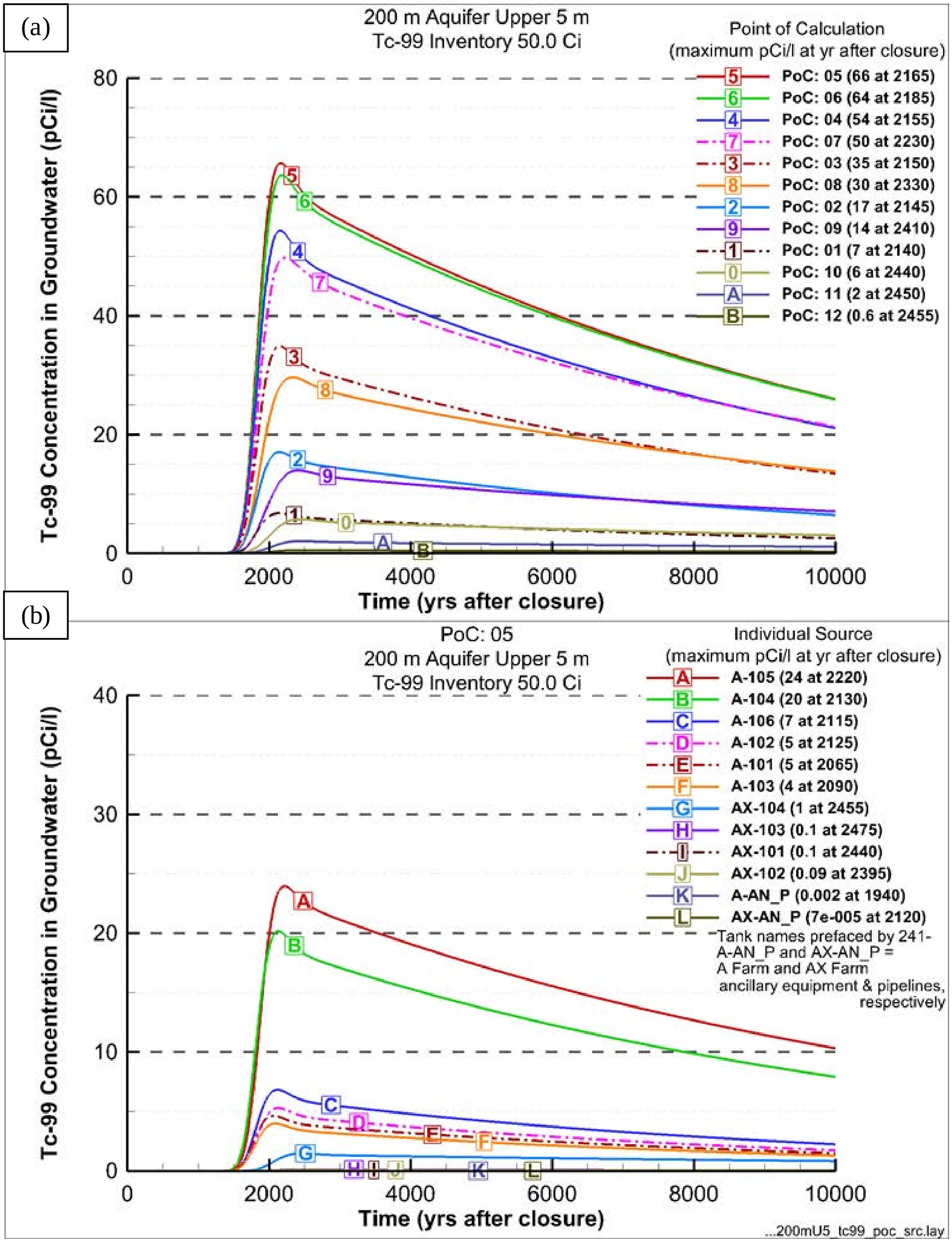
WMA = Waste Management Area

Figure 7-4. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration at the Groundwater Points of Calculation 100 meters from Waste Management Area A-AX for the Representative Tanks Identified in RPP-RPT-60885.



Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

1 **Figure 7-5. Waste Management Area A-AX Process Model Evaluation of Technetium-99**
2 **Concentration 200 meters from Waste Management Area A-AX (a) for the Groundwater**
3 **Points of Calculation and (b) for the Individual Components at the Point of Calculation**
4 **Where the Maximum Concentration Occurs.**
5



6
7 WMA = Waste Management Area

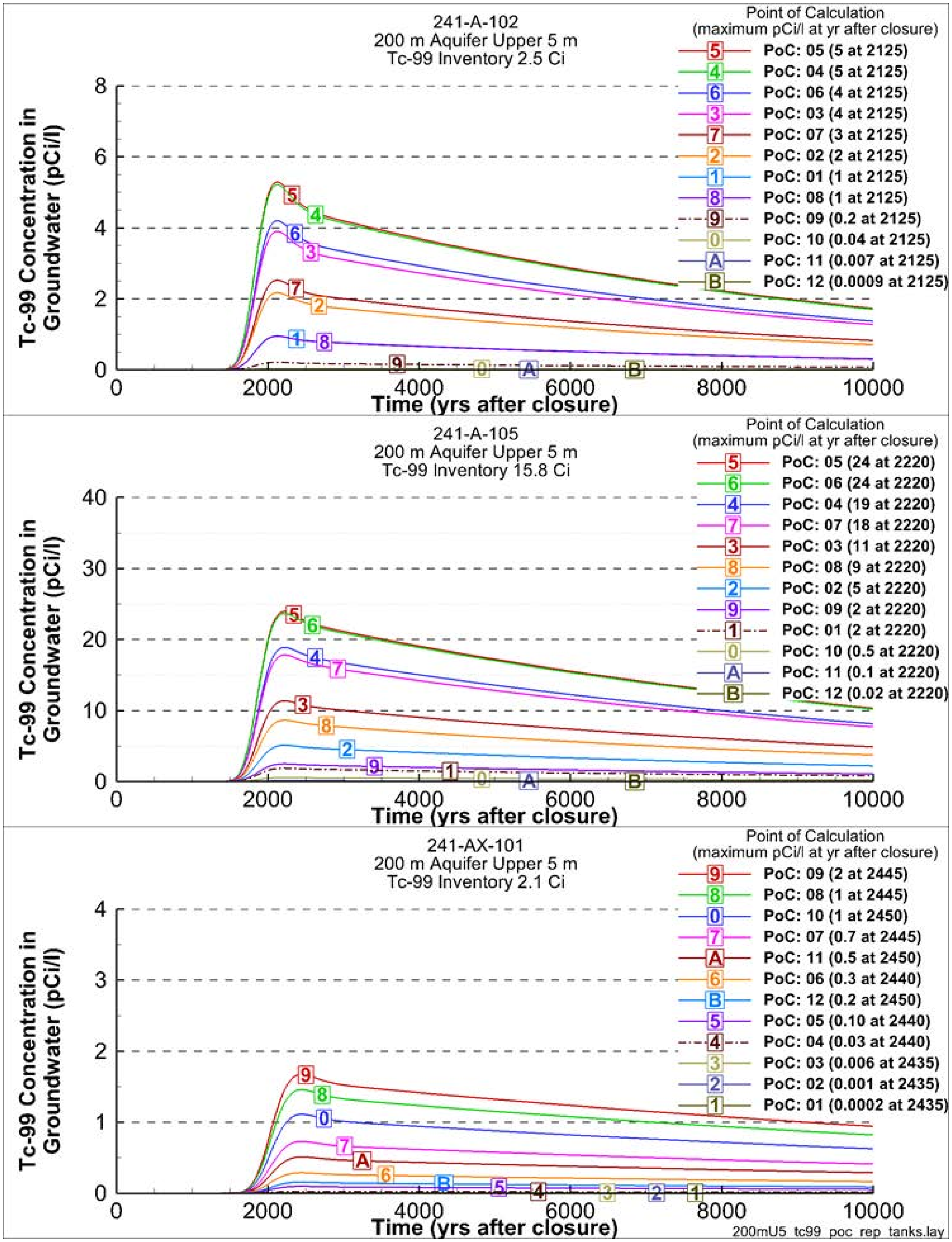
Figure 7-6 shows the breakthrough of ^{99}Tc from the three representative tanks at the 12 PoCals 200 m from WMA A-AX. The breakthrough curves shown in Figure 7-6 are similar to those shown in Figure 7-2 and Figure 7-4, but the magnitude of the groundwater concentration values further decreases because of the additional transport through the aquifer. The arrival times of the peak concentration at the PoCals 200 m from WMA A-AX are essentially identical to those that occur at the WMA A-AX fence line and 100 m from WMA A-AX.

Figure 7-7 shows the combined or cumulative plume of ^{99}Tc in groundwater from all the sources at the approximate time the peak concentration occurs 100 m from WMA A-AX. As indicated by the breakthrough curves, the center of the plume appears to pass through PoCal 5, and the ^{99}Tc released from tanks 241-A-105 and 241-A-104 appear to be the two largest sources of ^{99}Tc that produce the plume. Figure 7-8, Figure 7-9 , and Figure 7-10 show the plumes of ^{99}Tc that the sources from the three representative tanks, 241-A-102, 241-A-105, and 241-AX-101, respectively, produce individually. Figure 7-11 shows the contaminant flux and cumulative breakthrough of ^{99}Tc into groundwater from all the sources combined and individually. The arrival times of the peak fluxes of ^{99}Tc into groundwater coincide with the arrival times of the peak concentration in groundwater, which is consistent with the groundwater flow velocity and the analysis in RPP-RPT-60885.

Figure 7-12 through Figure 7-17 show example contaminant breakthrough curves of ^{129}I. Figure 7-12 shows the combined or cumulative breakthrough of ^{129}I from all the sources at the 12 PoCals along the line of evaluation approximating the fence line of WMA A-AX, and the contribution from each source identified at the PoCal where the highest concentration occurs. The highest peak concentration occurs within PoCal 4, although the peak concentration within PoCal 3 is close. The ^{129}I released from the A Farm ancillary equipment, including pipelines, and tank 241-A-104 represents the two largest components of that peak concentration. The contribution from each of those two sources at the time of the peak concentration is more than three times the contribution of any other source. The peak concentration at the PoCal where the maximum concentration occurs is 0.002 pCi/L, which is about a factor of 500 less than the EPA MCL of 1 pCi/L. Figure 7-13 shows the breakthrough of ^{129}I from the three representative tanks at the 12 PoCals along the fence line of WMA A-AX.

Figure 7-14 shows the combined or cumulative breakthrough of ^{129}I from all the sources at the 12 PoCals along the line of evaluation 100 m from WMA A-AX, and the contribution from each source identified at the PoCal where the highest concentration occurs. The highest peak concentration remains occurring within PoCal 4, with the peak concentration within PoCal 3 being very close. The ^{129}I released from the A Farm ancillary equipment and tank 241-A-104 remains the two largest components of that peak concentration. The contribution from each of those two sources at this distance from WMA A-AX at the time of the peak concentration is about three times the contribution of any other source. The peak concentration at the PoCal where the maximum concentration occurs is 0.002 pCi/L, which is the same as the peak concentration at the fence line, and about a factor of 500 less than the drinking water standard. Figure 7-15 shows the breakthrough of ^{129}I from the three representative tanks at the 12 PoCals along the fence line of WMA A-AX.

Figure 7-6. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration at the Groundwater Points of Calculation 200 meters from Waste Management Area A-AX for the Representative Tanks Identified in RPP-RPT-60885.



Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-7. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration in Groundwater at Top of Water Table from All Sources for Year 4050, the Approximate Time the Maximum Concentration Occurs.

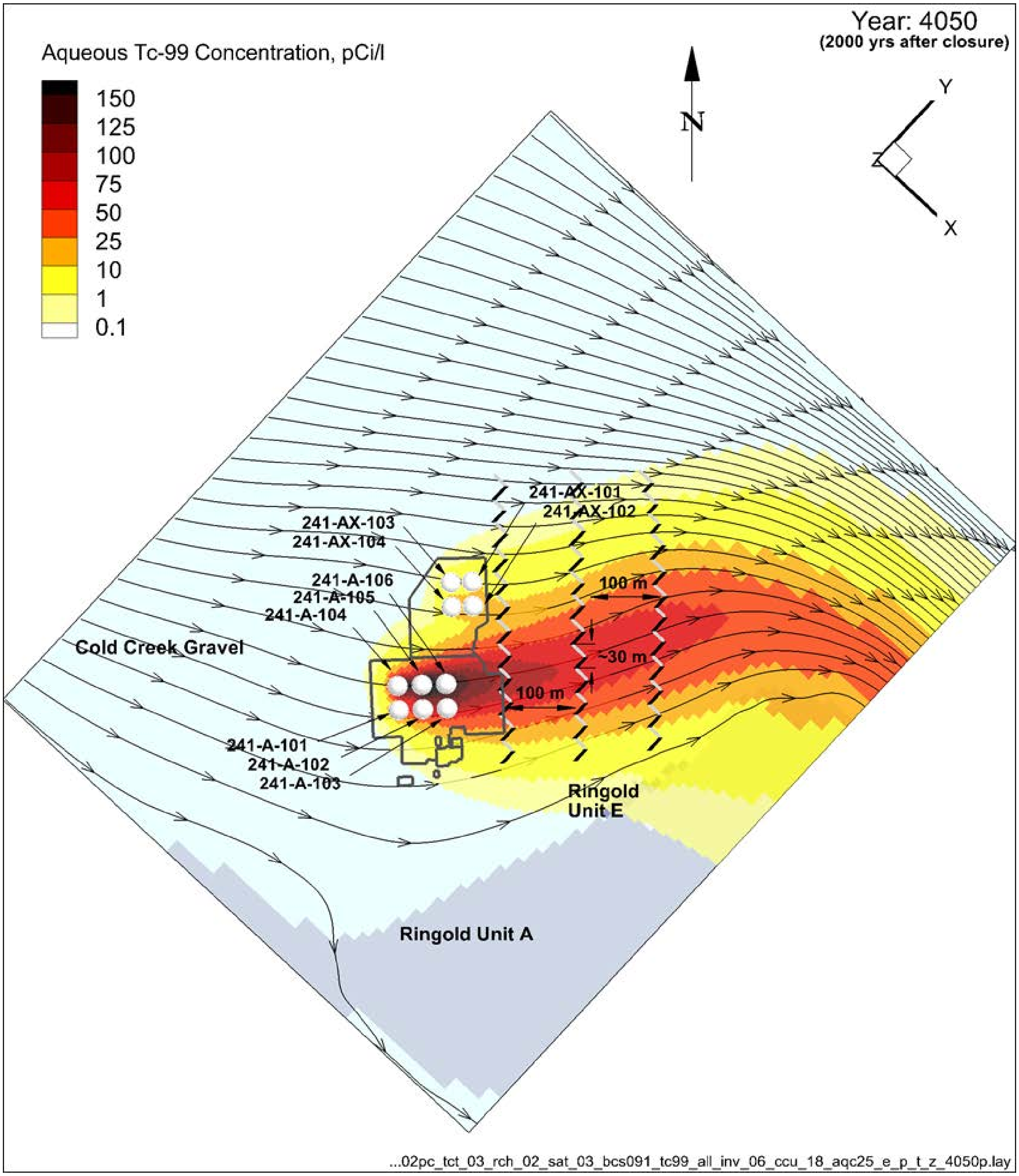
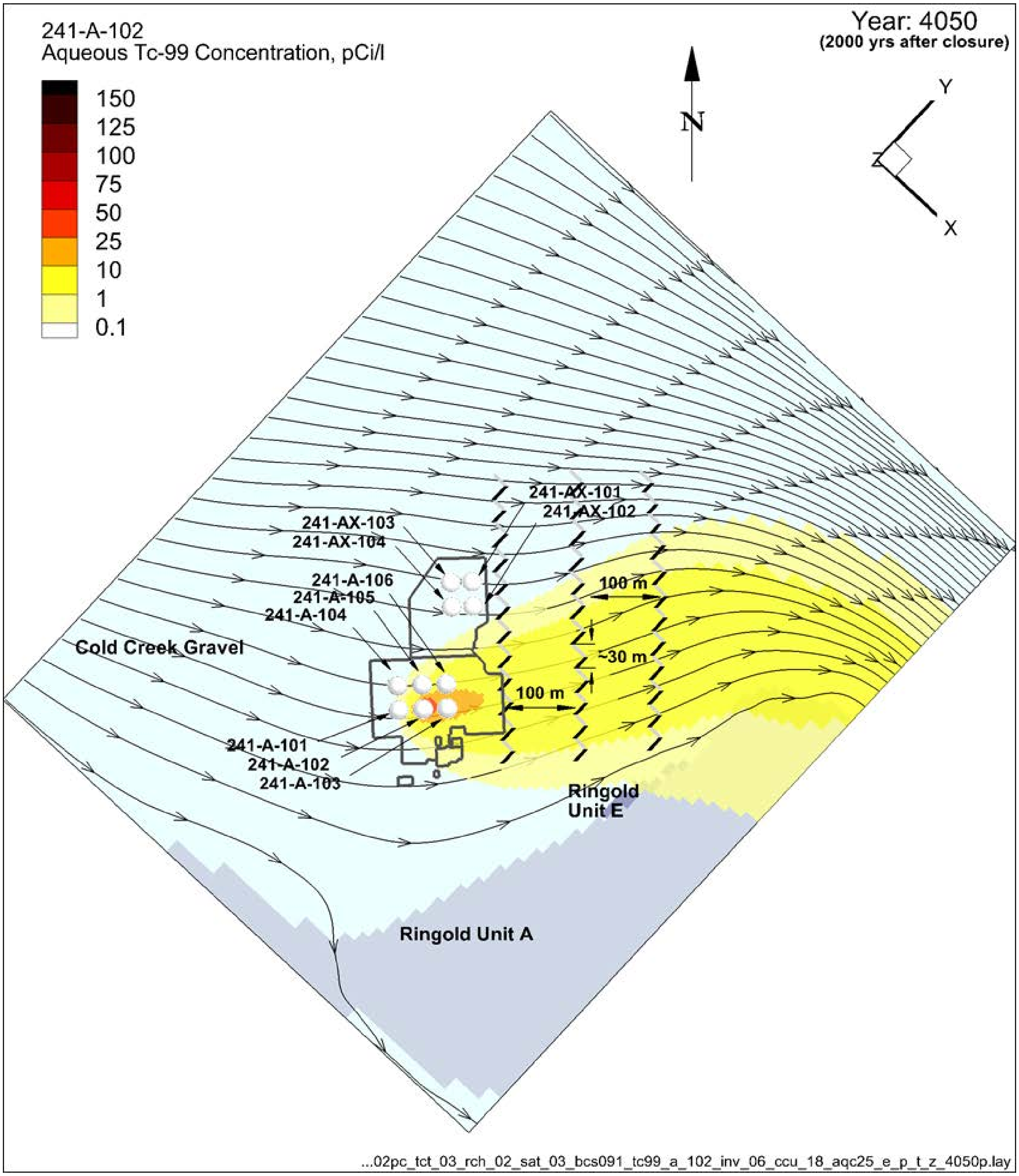
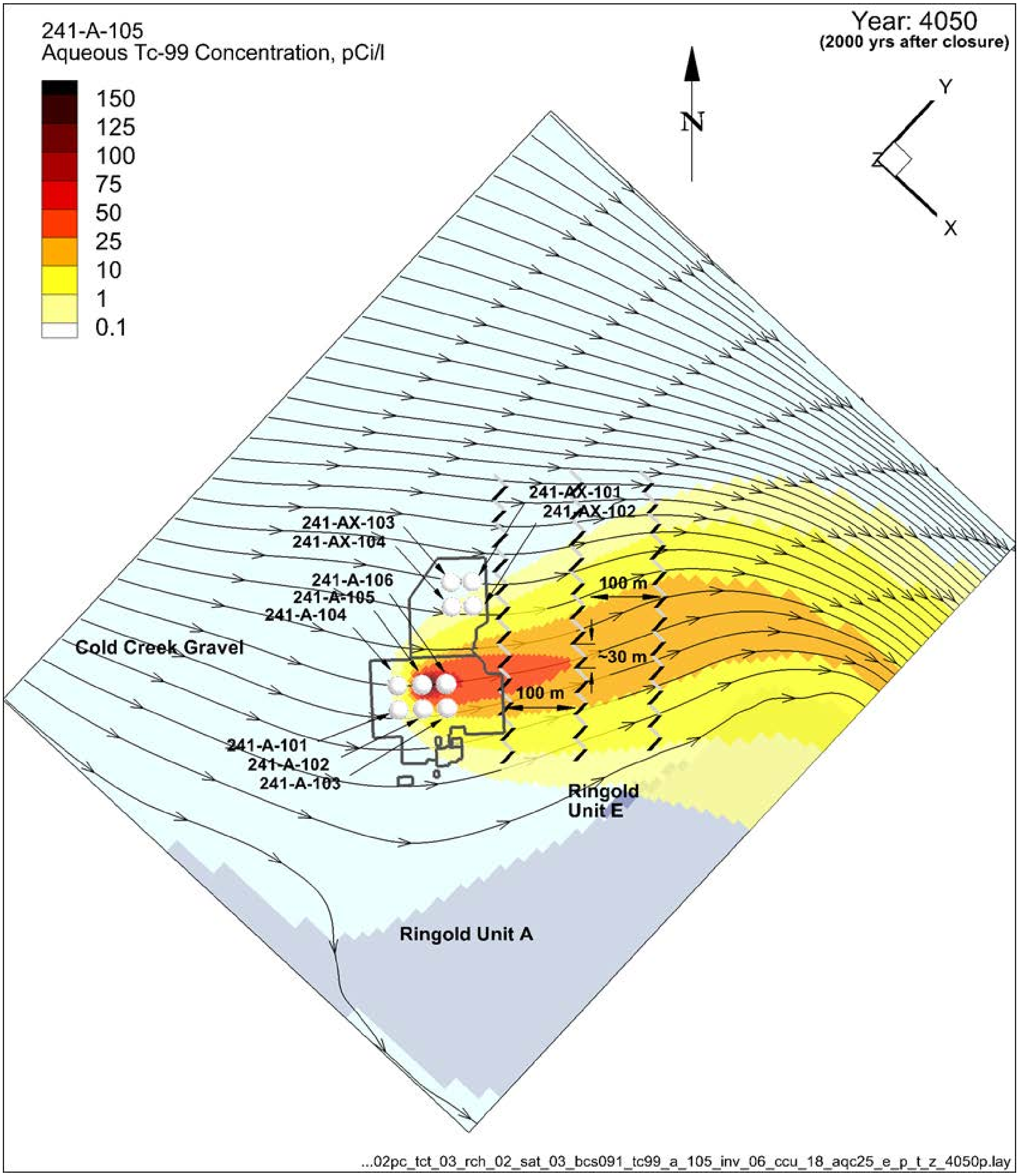


Figure 7-8. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration in Groundwater at Top of Water Table from Tank 241-A-102, One of the Representative Tanks Identified in RPP-RPT-60885, for Year 4050, the Approximate Time the Maximum Concentration Occurs.



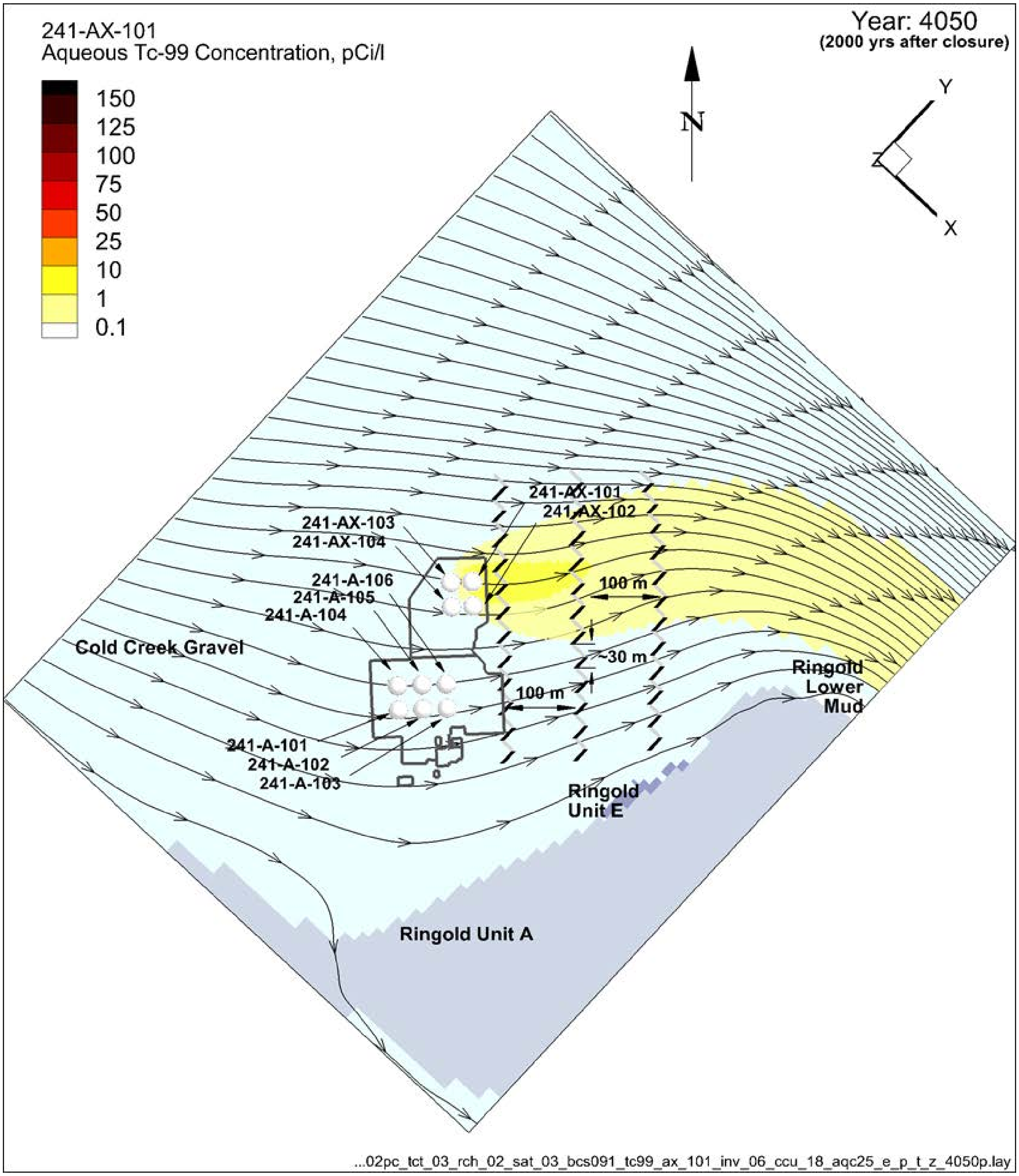
Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-9. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration in Groundwater at Top of Water Table from Tank 241-A-105, One of the Representative Tanks Identified in RPP-RPT-60885, for Year 4050, the Approximate Time the Maximum Concentration Occurs.



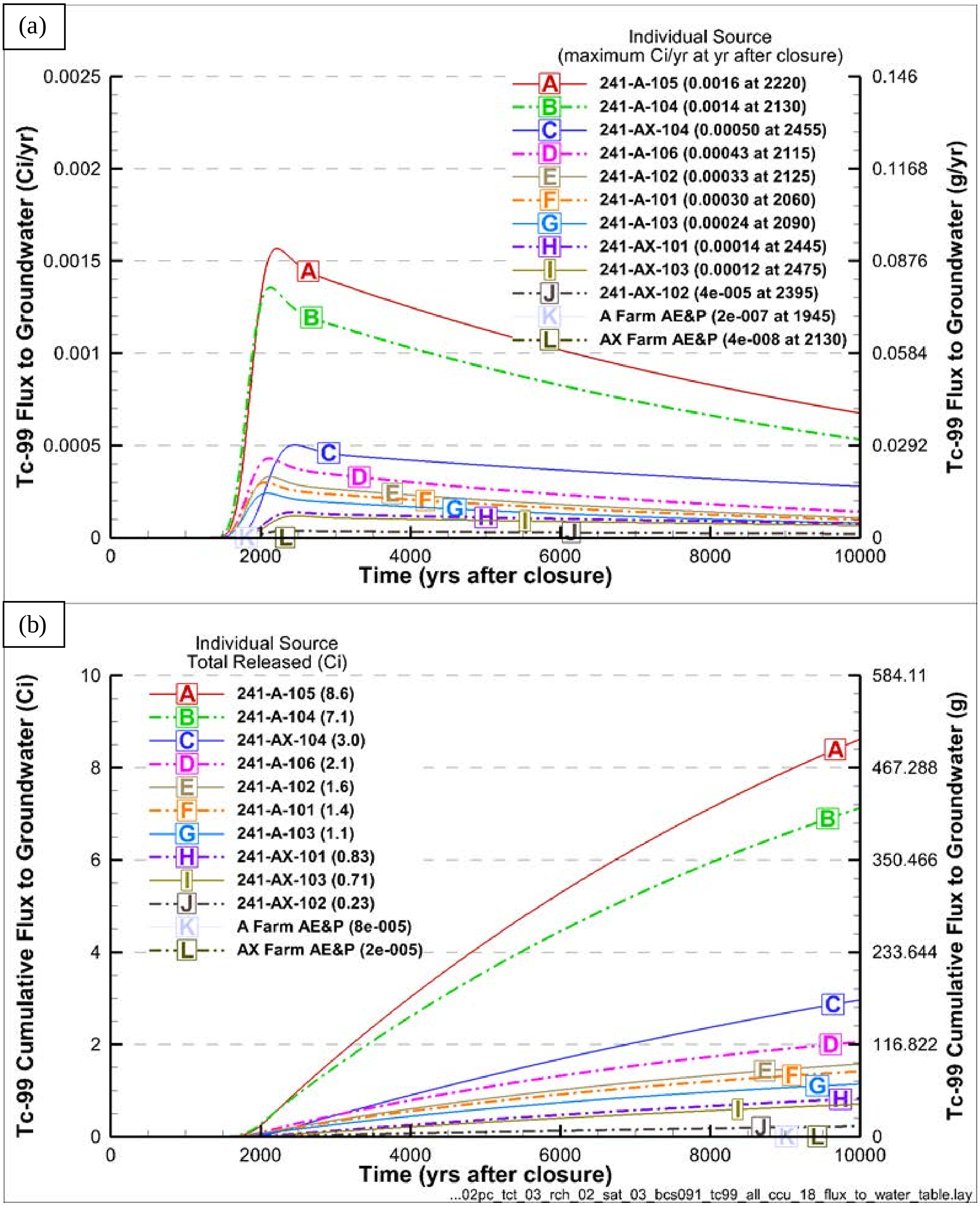
Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-10. Waste Management Area A-AX Process Model Evaluation of Technetium-99 Concentration in Groundwater at Top of Water Table from Tank 241-AX-101, One of the Representative Tanks Identified in RPP-RPT-60885, for Year 4050, the Approximate Time the Maximum Concentration Occurs.



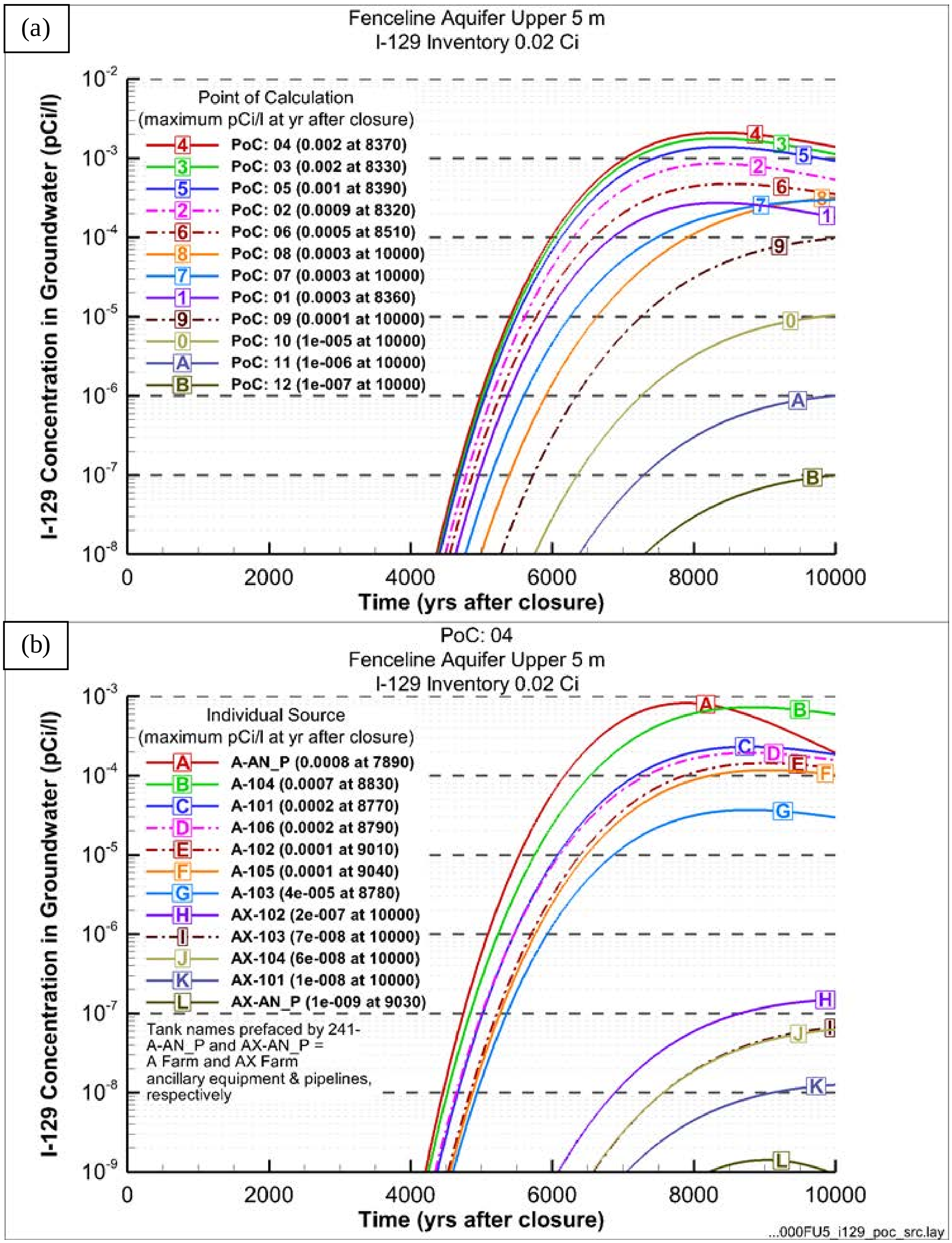
Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-11. Waste Management Area A-AX Process Model Evaluation of Technetium-99 (a) Mass Flux to Groundwater and (b) Cumulative Mass Breakthrough to Groundwater.



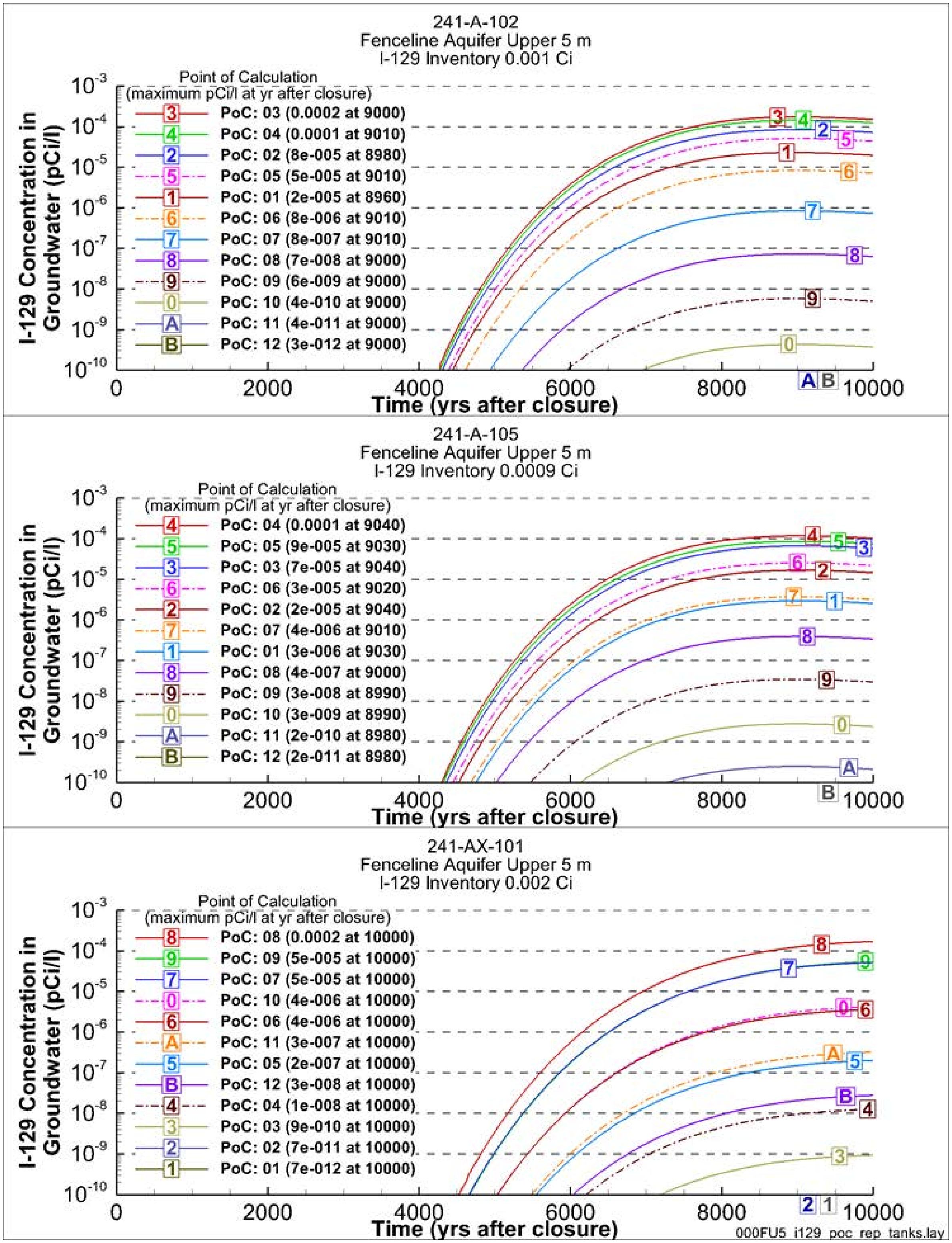
AE&P = ancillary equipment and pipelines

Figure 7-12. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration at the Waste Management Area A-AX Fence Line (a) for the Groundwater Points of Calculation and (b) for the Individual Components at the Point of Calculation Where the Maximum Concentration Occurs.



WMA = Waste Management Area

Figure 7-13. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration at the Groundwater Points of Calculation at the Fence Line for the Representative Tanks Identified in RPP-RPT-60885..



Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-14. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration 100 meters from Waste Management Area A-AX (a) for the Groundwater Points of Calculation and (b) for the Individual Components at the Point of Calculation Where the Maximum Concentration Occurs.

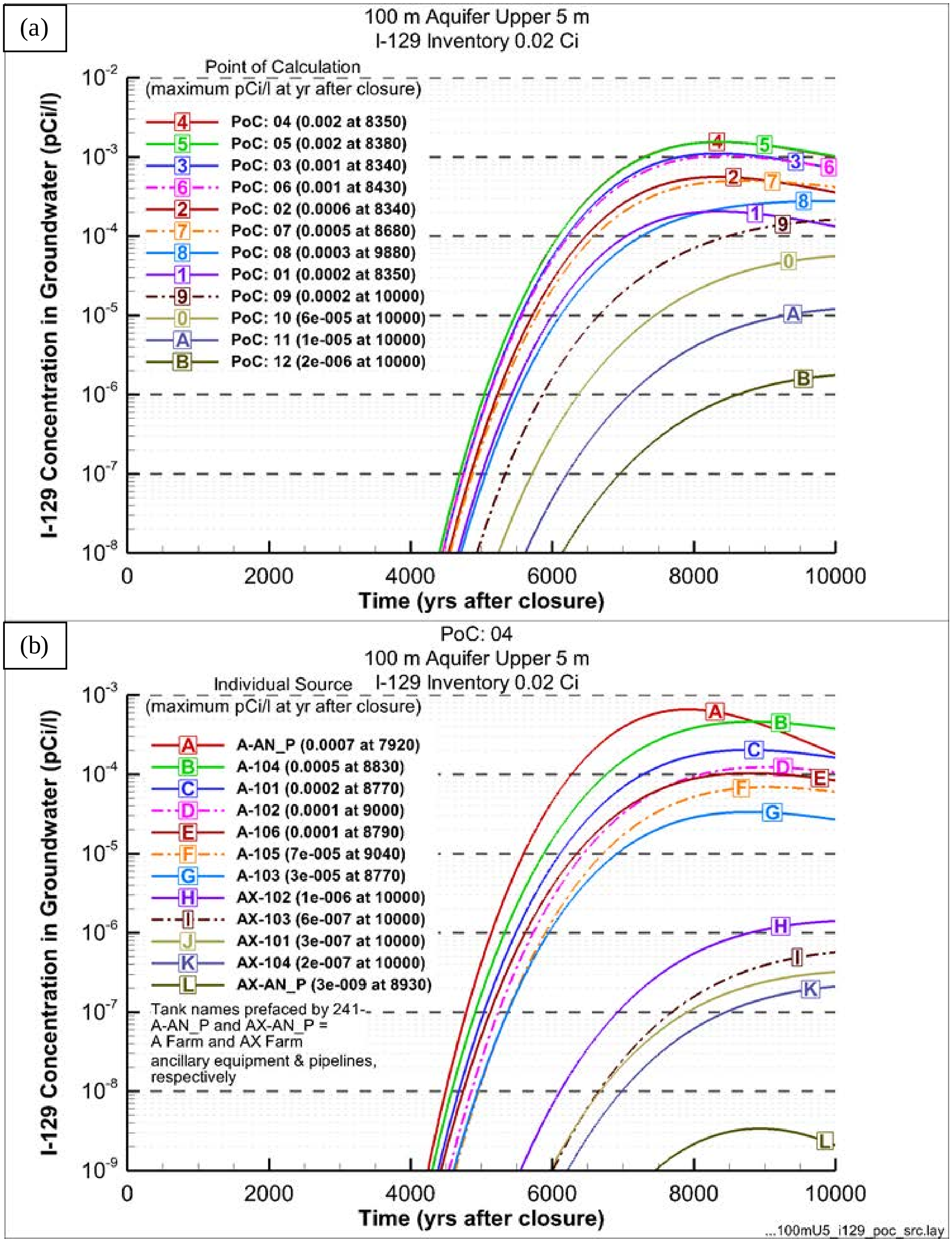
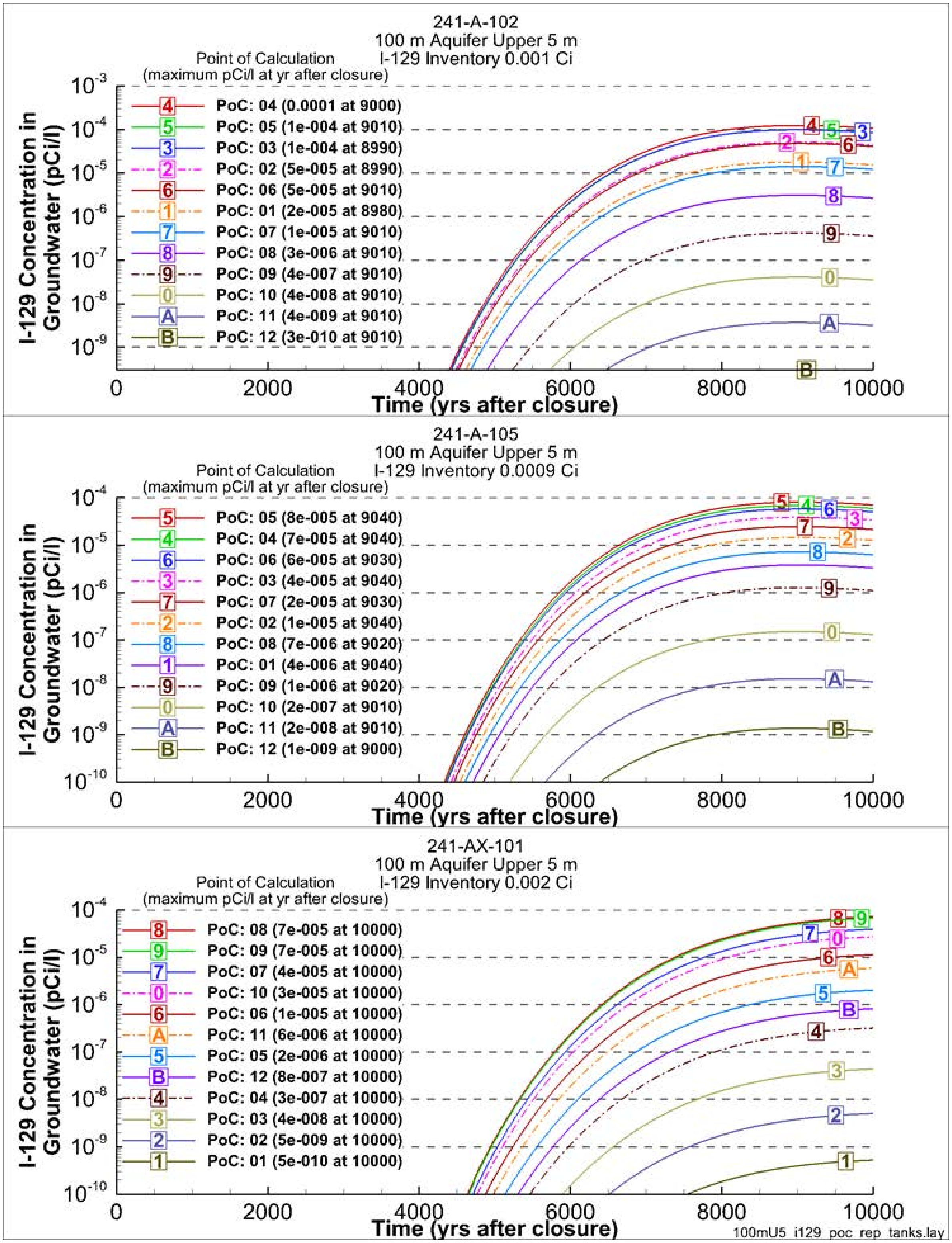


Figure 7-15. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration at the Groundwater Points of Calculation 100 meters from Waste Management Area A-AX for the Representative Tanks Identified in RPP-RPT-60885.



Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-16 shows the combined or cumulative breakthrough of ^{129}I from all the sources at the 12 PoCals along the line of evaluation 200 m from WMA A-AX, and the contribution from each source identified at the PoCal where the highest concentration occurs. The highest peak concentration along this line occurs within PoCal 5, but the peak concentration within PoCals 3, 4, and 6 are essentially the same. The ^{129}I released from the A Farm ancillary equipment and tank 241-A-104 remains the two largest components of that peak concentration, and is two to three times the contribution of any other source. The peak concentration at the PoCal where the maximum concentration occurs is 0.001 pCi/L, which is about a factor of 1,000 less than the EPA MCL. Figure 7-17 shows the breakthrough of ^{129}I from the three representative tanks at the 12 PoCals along the fence line of WMA A-AX.

Figure 7-18 shows the combined or cumulative plume of ^{129}I in groundwater from all the sources at the approximate time the peak concentration occurs 100 m from WMA A-AX. The peak concentration occurs around 8,000 years after the assumed closure of WMA A-AX, near the end of the 10,000 year sensitivity/uncertainty time frame. As indicated by the breakthrough curves, the center of the plume appears to pass through PoCal 4 and PoCal 5. The ^{129}I associated with the release from the A Farm ancillary equipment is the largest contributor to the plume, and the ^{129}I associated with the release from tank 241-A-104 is the second largest contributor. Figure 7-19 shows the contaminant flux and cumulative breakthrough of ^{129}I into groundwater from all the sources combined and individually. The arrival times of the peak fluxes of ^{129}I into groundwater coincide with the arrival times of the peak concentration in groundwater, which is consistent with the groundwater flow velocity and the analysis in RPP-RPT-60885.

In comparison to the breakthrough curves associated with the releases of ^{99}Tc, the ^{129}I breakthrough curves indicate that the magnitude of the groundwater concentration values, and in particular the maximum concentration values, is substantially less. The arrival of the ^{129}I peak concentration values occurs about 4,000 years after the arrival of the peak ^{99}Tc concentration values because of the retardation ^{129}I experiences during transport through the vadose zone. However, the peak ^{129}I concentration arrival times are essentially the same at the PoCals at the fence line, 100 m from WMA A-AX, or 200 m from WMA A-AX, even though the distribution coefficient of ^{129}I indicates that its transport through the aquifer is slightly retarded.

The results of the process modeling indicate that ^{99}Tc reaches the groundwater PoCals at the fence line, 100 m from WMA A-AX, and 200 m from WMA A-AX within the DOE O 435.1 compliance period of 1,000 years. Iodine-129 does not reach the water table during the compliance period. The concentration of ^{99}Tc in groundwater during the compliance period is essentially negligible in value (Table 7-1, Table 7-2, and Table 7-3, respectively). The maximum concentration of ^{99}Tc occurs about 2,100 years after the assumed closure of WMA A-AX at all three of the lines of analysis, with the maximum concentration values in any one PoCal being 110 pCi/L, 77 pCi/L, and 66 pCi/L at the fence line, 100 m from WMA A-AX, and 200 m from WMA A-AX, respectively. The maximum concentration of ^{129}I occurs more than 8,000 years after the assumed closure of WMA A-AX at all three of the lines of analysis. The maximum concentration values in any one PoCal are 0.002 pCi/L, 0.002 pCi/L, and 0.001 pCi/L at the fence line, 100 m from WMA A-AX, and 200 m from WMA A-AX, respectively (Table 7-1, Table 7-2, and Table 7-3). All the concentration values for ^{99}Tc and ^{129}I are substantially below the EPA MCLs for these two radionuclides (900 pCi/L and 1 pCi/L, respectively).

Figure 7-16. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration 200 meters from Waste Management Area A-AX (a) for the Groundwater Points of Calculation and (b) for the Individual Components at the Point of Calculation Where the Maximum Concentration Occurs.

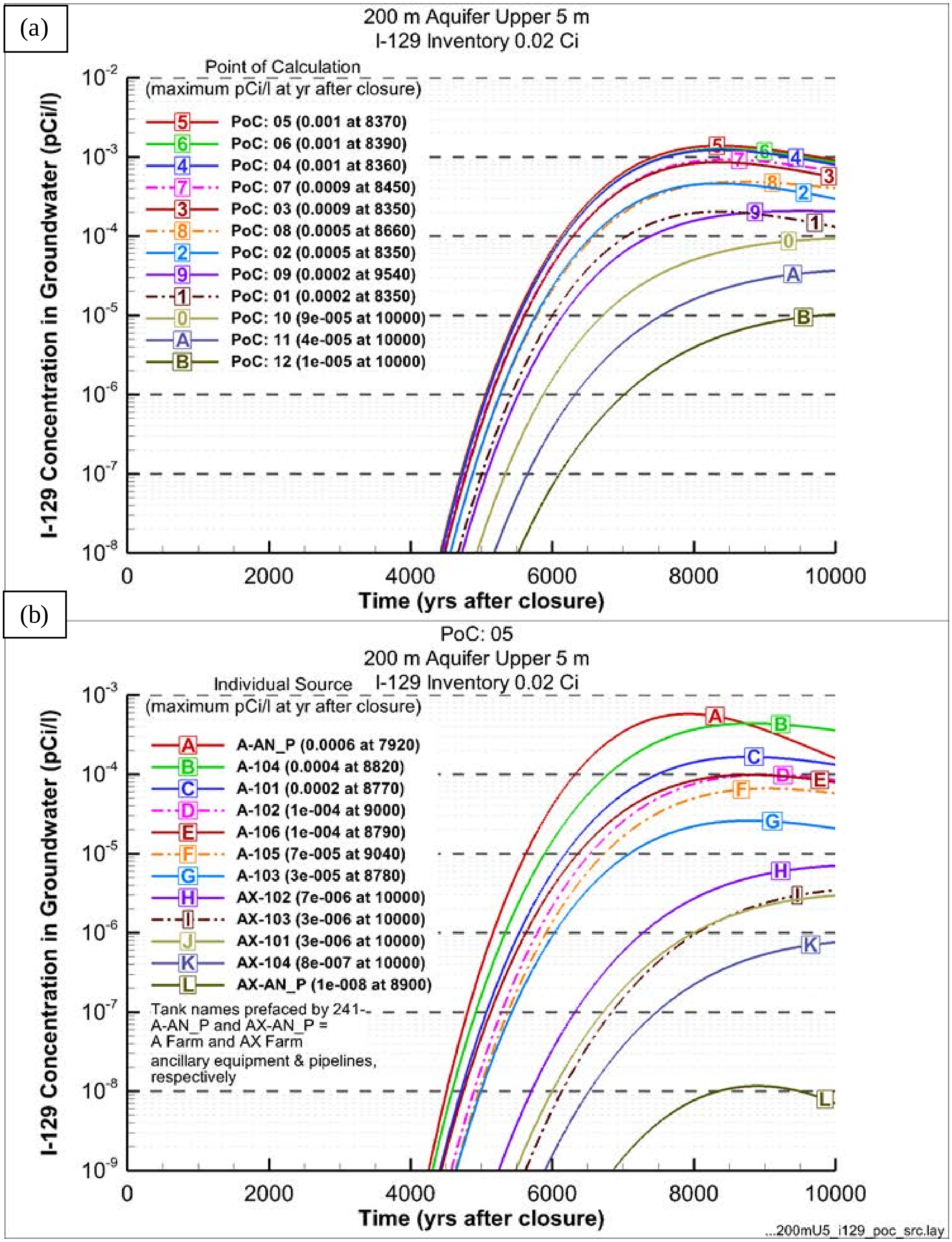
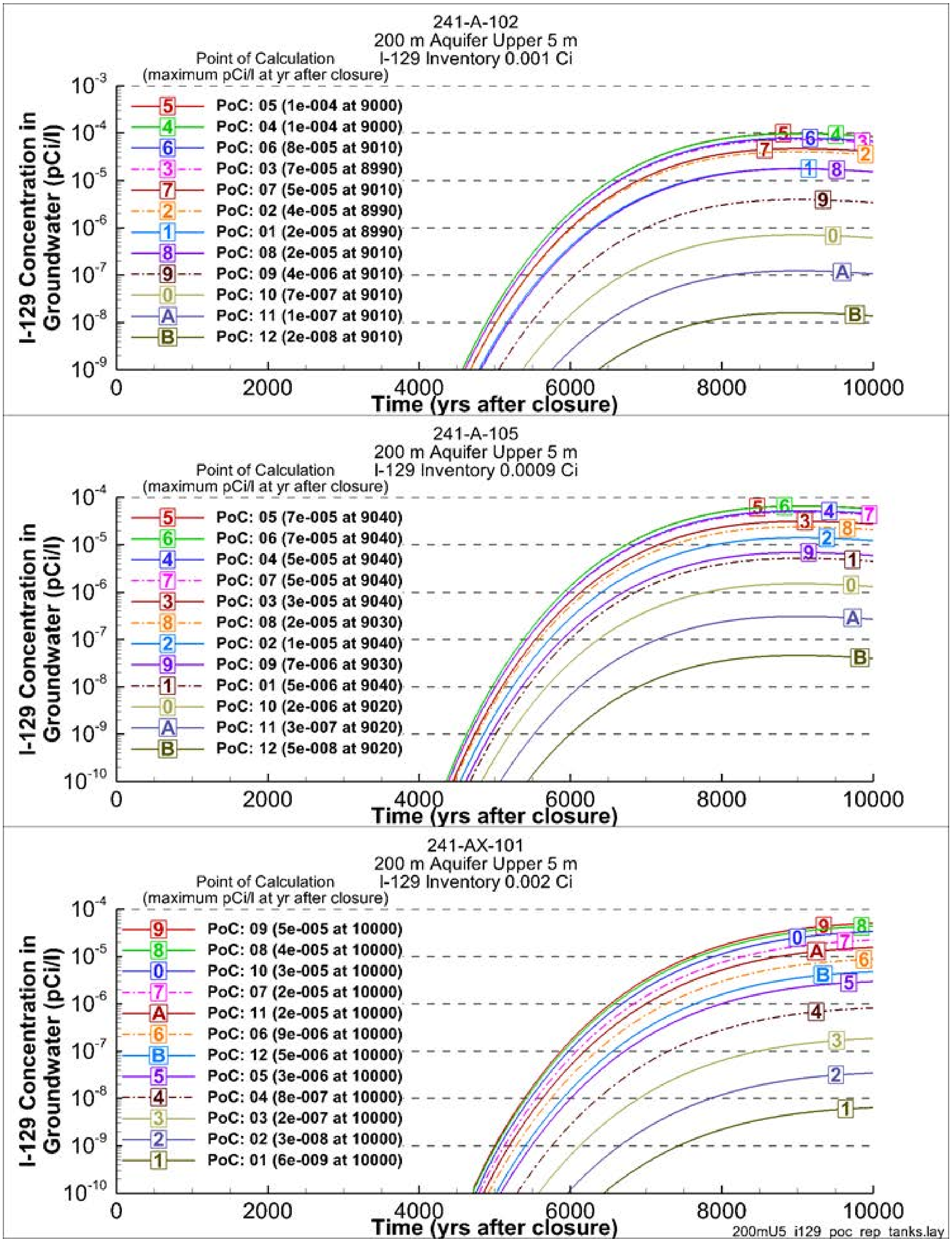
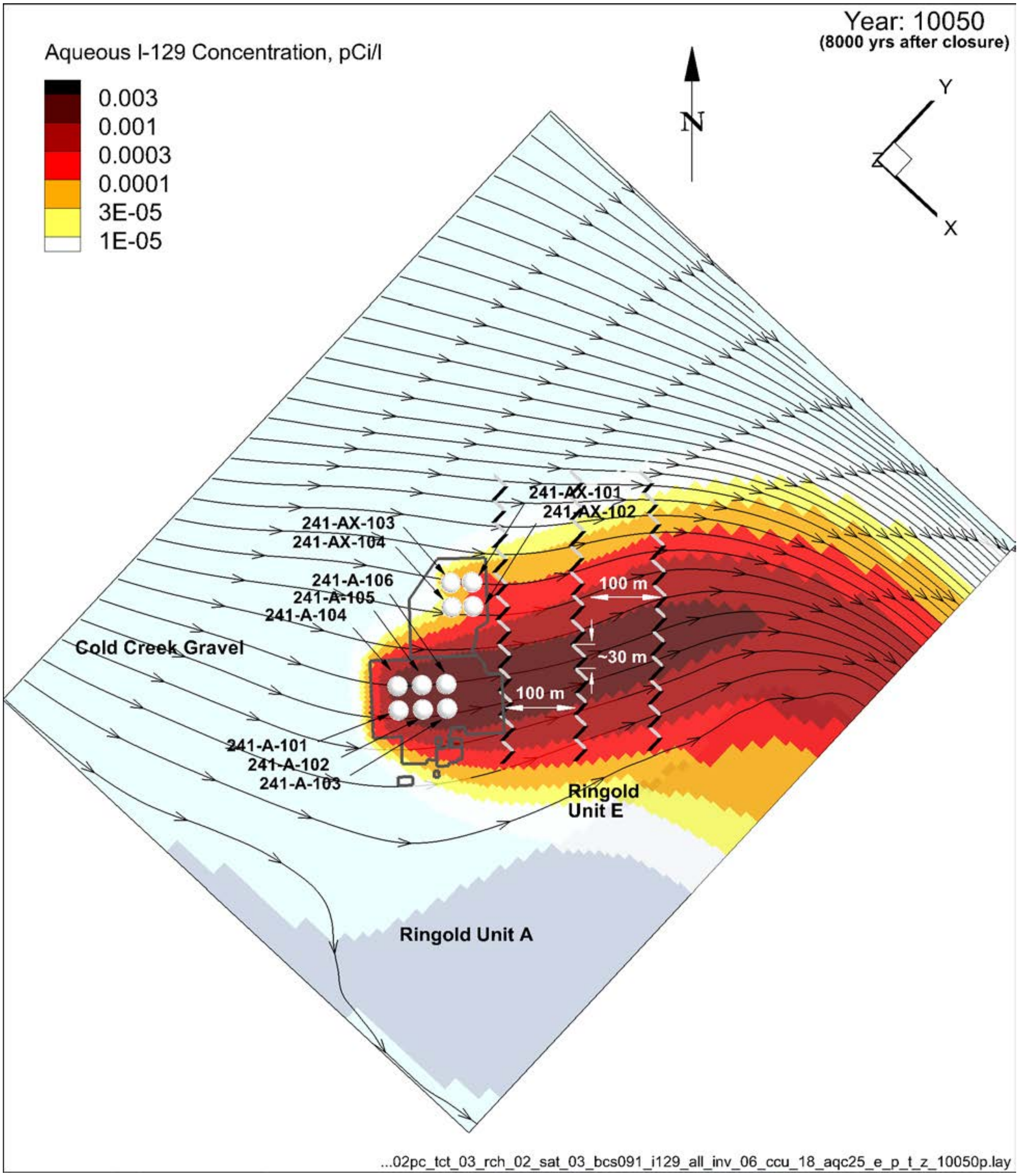


Figure 7-17. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration at the Groundwater Points of Calculation 200 meters from Waste Management Area A-AX for the Representative Tanks Identified in RPP-RPT-60885.

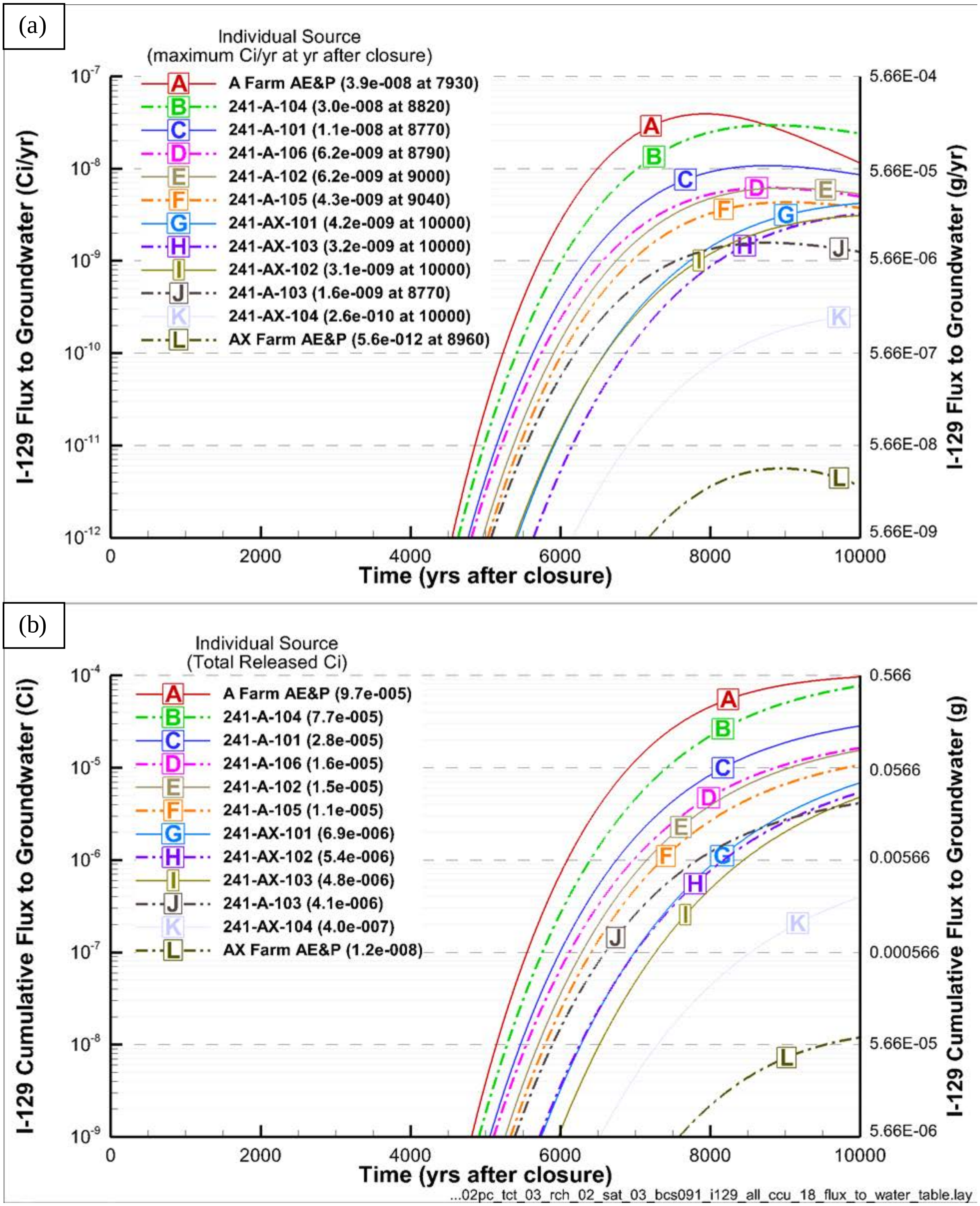


Reference: RPP-RPT-60885, *Model Package Report System Model for the WMA A-AX Performance Assessment*.

Figure 7-18. Waste Management Area A-AX Process Model Evaluation of Iodine-129 Concentration in Groundwater at Top of Water Table from All Sources for Year 10050, the Approximate Time the Maximum Concentration Occurs.



1 **Figure 7-19. Waste Management Area A-AX Process Model Evaluation of Iodine-129 (a)**
2 **Mass Flux to Groundwater and (b) Cumulative Mass Breakthrough to Groundwater.**
3



4
5 AE&P = ancillary equipment and pipelines

Table 7-1. Maximum Groundwater Concentration at the Points of Calculation at the Fence Line of Waste Management Area A-AX during the Compliance and Sensitivity/Uncertainty Time Periods.

Fence Line Point of Calculation (PoCal)	Technetium-99 Nominal K_d value: 0 mL/g			Iodine-129 Nominal K_d value: 0.2 mL/g		
	Maximum Concentration during 1,000-year Compliance Time Frame (pCi/L)	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration	Maximum Concentration during 1,000-year Compliance Time Frame (pCi/L)	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration
PoCal 1	6E-18	6	2,120	0	0.0003	8,360
PoCal 2	3E-16	26	2,130	0	0.0009	8,320
PoCal 3	4E-15	76	2,145	0	0.002	8,330
PoCal 4	5E-15	110	2,160	0	0.002	8,370
PoCal 5	1E-15	73	2,170	0	0.001	8,390
PoCal 6	2E-14	29	2,325	0	0.0005	8,510
PoCal 7	4E-13	24	2,445	0	0.0003	10,000
PoCal 8	1E-12	17	2,455	0	0.0003	10,000
PoCal 9	1E-13	4	2,460	0	0.0001	10,000
PoCal 10	5E-17	0.5	2,460	0	0.00001	10,000
PoCal 11	0	0.05	2,465	0	0.000001	10,000
PoCal 12	0	0.005	2,465	0	1E-07	10,000

Table 7-2. Maximum Groundwater Concentration at the Points of Calculation 100 meters from Waste Management Area A-AX during the Compliance and Sensitivity/Uncertainty Time Periods.

100-meter Point of Calculation (PoCal)	Technetium-99 Nominal K_d value: 0 mL/g			Iodine-129 Nominal K_d value: 0.2 mL/g		
	Maximum Concentration during 1,000-year Compliance Time Frame (pCi/L)	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration	Maximum Concentration during 1,000-year Compliance Time Frame (pCi/L)	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration
PoCal 1	3E-21	6	2,130	0	0.0002	8,350
PoCal 2	4E-20	19	2,140	0	0.0006	8,340
PoCal 3	2E-19	44	2,145	0	0.001	8,340
PoCal 4	4E-19	71	2,155	0	0.002	8,350
PoCal 5	5E-19	77	2,170	0	0.002	8,380
PoCal 6	1E-18	56	2,210	0	0.001	8,430
PoCal 7	5E-18	32	2,350	0	0.0005	8,680
PoCal 8	9E-18	19	2,425	0	0.0003	9,880
PoCal 9	7E-18	10	2,450	0	0.0002	10,000
PoCal 10	9E-19	3	2,455	0	0.00006	10,000
PoCal 11	2E-20	0.6	2,460	0	0.00001	10,000
PoCal 12	2E-22	0.08	2,460	0	0.000002	10,000

Table 7-3. Maximum Groundwater Concentration at the Points of Calculation 200 meters from Waste Management Area A-AX during the Compliance and Sensitivity/Uncertainty Time Periods.

200-meter Point of Calculation (PoCal)	Technetium-99 Nominal K_d value: 0 mL/g			Iodine-129 Nominal K_d value: 0.2 mL/g		
	Maximum Concentration during 1,000-year Compliance Time Frame (pCi/L)	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration	Maximum Concentration during 1,000-year Compliance Time Frame (pCi/L)	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration
PoCal 1	0	7	2,140	0	0.0002	8,350
PoCal 2	0	17	2,145	0	0.0005	8,350
PoCal 3	0	35	2,150	0	0.0009	8,350
PoCal 4	0	54	2,155	0	0.001	8,360
PoCal 5	0	66	2,165	0	0.001	8,370
PoCal 6	0	64	2,185	0	0.001	8,390
PoCal 7	0	50	2,230	0	0.0009	8,450
PoCal 8	1E-22	30	2,330	0	0.0005	8,660
PoCal 9	1E-22	14	2,410	0	0.0002	9,540
PoCal 10	7E-23	6	2,440	0	0.00009	10,000
PoCal 11	0	2	2,450	0	0.00004	10,000
PoCal 12	0	0.6	2,455	0	0.00001	10,000

1

Table 7-4, Table 7-5, and Table 7-6 provide a breakdown of the ^{99}Tc and ^{129}I results at the three groundwater lines of analysis according to the individual sources and the specific PoCal where the maximum concentration occurs for each source. The maximum concentrations of ^{99}Tc associated with sources in A Farm occur within PoCals 3, 4, and 5, and the maximum concentrations of ^{99}Tc associated with sources in AX Farm occur within PoCals 7, 8, and 9, indicating that there is little interaction between the sources from the different tank farms. The sources responsible for the three highest individual maximum concentrations of ^{99}Tc in any one PoCal at the fence line of WMA A-AX are tanks 241-A-105 (43 pCi/L), 241-A-104 (34 pCi/L), and 241-AX-104 (15 pCi/L). At the lines of analysis 100 m and 200 m from WMA A-AX, the sources from tanks 241-A-105 and 241-A-104 produce the highest groundwater concentration of ^{99}Tc (30 pCi/L and 24 pCi/L for 241-A-105, respectively, and 24 pCi/L and 20 pCi/L for 241-A-104, respectively). The sources from tanks 241-AX-104 and 241-A-106 produce essentially the same maximum concentration value at these two lines of analysis (9 pCi/L at 100 m from WMA A-AX and 7 pCi/L at 200 m from WMA A-AX), which are the next highest values at those two lines.

The sources responsible for the three highest individual maximum concentrations of ^{129}I in any one PoCal at all three lines of analysis for WMA A-AX are the A Farm ancillary equipment, including pipelines, and tanks 241-A-104 and 241-A-101, in that order. The sources responsible for the three highest maximum ^{129}I groundwater concentration values and their order do not change at the three lines of analysis. At the fence line, the three highest values are 0.0008 pCi/L, 0.0007 pCi/L, and 0.0003 pCi/L. At 100 m from WMA A-AX the three highest values are 0.0007 pCi/L, 0.0005 pCi/L, and 0.0002 pCi/L, and at 200 m from WMA A-AX the three highest values are 0.0006 pCi/L, 0.0004 pCi/L, and 0.0002 pCi/L.

Table 7-7, Table 7-8, and Table 7-9 provide a comprehensive breakdown of the ^{99}Tc maximum groundwater concentration results at the three groundwater lines of analysis for each of the individual sources and all the PoCals. Table 7-10, Table 7-11, and Table 7-12 provide a similar breakdown of the ^{129}I maximum groundwater concentration results at the three groundwater lines of analysis for each of the individual sources and all the PoCals.

7.1.2 Model Evaluation

Model evaluation consists of demonstrating that the model and model results satisfy the objectives of modeling. The objective of the WMA A-AX PA flow and transport process model is to estimate future contaminant concentrations in groundwater of ^{99}Tc and ^{129}I associated with waste remaining in tank residuals after closure of WMA A-AX. The ^{99}Tc and ^{129}I transport simulations provide benchmark results to assist in the development of the vadose and saturated zone system model (RPP-RPT-60885), which is intended to include the base case evaluation of the radionuclides and contaminants of potential concern (RPP-CALC-62538). Therefore, model evaluation of the process model consists of demonstrating the adequacy of the eSTOMP simulations to produce those results, demonstrating that the results are numerically stable, and demonstrating that impacts of numerical dispersion on the differential equation solutions are not large enough to negate the use of the model or its results.

Table 7-4. Maximum Groundwater Concentration and Point of Calculation of the Individual Sources at the Fence Line of Waste Management Area A-AX during the Compliance and Sensitivity/Uncertainty Time Periods.

Individual Source	Technetium-99 Nominal K_d value: 0 mL/g			Iodine-129 Nominal K_d value: 0.2 mL/g		
	Point of Calculation of Maximum Concentration	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration	Point of Calculation of Maximum Concentration	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration
241-A-101	PoCal 03	8	2,060	PoCal 03	0.0003	8,770
241-A-102	PoCal 03	9	2,125	PoCal 03	0.0002	9,000
241-A-103	PoCal 03	8	2,090	PoCal 03	0.00005	8,770
241-A-104	PoCal 04	34	2,130	PoCal 04	0.0007	8,830
241-A-105	PoCal 04	43	2,220	PoCal 04	0.0001	9,040
241-A-106	PoCal 04	13	2,115	PoCal 04	0.0002	8,790
A Farm AE&P	PoCal 04	0.003	1,935	PoCal 04	0.0008	7,890
241-AX-101	PoCal 08	6	2,450	PoCal 08	0.0002	10,000
241-AX-102	PoCal 07	2	2,400	PoCal 07	0.0001	10,000
241-AX-103	PoCal 08	3	2,475	PoCal 08	0.00009	10,000
241-AX-104	PoCal 07	15	2,460	PoCal 07	0.000008	10,000
AX Farm AE&P	PoCal 07	0.0007	2,110	PoCal 07	1E-07	8,810

AE&P = Ancillary Equipment and Pipelines PoCal = Point of Calculation

Table 7-5. Maximum Groundwater Concentration and Point of Calculation of the Individual Sources 100 meters from Waste Management Area A-AX during the Compliance and Sensitivity/Uncertainty Time Period.

Individual Source	Technetium-99 Nominal K_d value: 0 mL/g			Iodine-129 Nominal K_d value: 0.2 mL/g		
	Point of Calculation of Maximum Concentration	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration	Point of Calculation of Maximum Concentration	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration
241-A-101	PoCal 04	6	2,065	PoCal 04	0.0002	8,770
241-A-102	PoCal 04	7	2,125	PoCal 04	0.0001	9,000
241-A-103	PoCal 04	5	2,090	PoCal 04	0.00003	8,770
241-A-104	PoCal 05	24	2,130	PoCal 05	0.0005	8,820
241-A-105	PoCal 05	30	2,220	PoCal 05	0.00008	9,040
241-A-106	PoCal 05	9	2,115	PoCal 05	0.0001	8,790
A Farm AE&P	PoCal 04	0.003	1,940	PoCal 04	0.0007	7,920
241-AX-101	PoCal 08	2	2,445	PoCal 08	0.00007	10,000
241-AX-102	PoCal 08	0.7	2,400	PoCal 08	0.00006	10,000
241-AX-103	PoCal 08	2	2,475	PoCal 08	0.00005	10,000
241-AX-104	PoCal 07	9	2,460	PoCal 07	0.000004	10,000
AX Farm AE&P	PoCal 08	0.0005	2,125	PoCal 08	8E-08	8,930

AE&P = Ancillary Equipment and Pipelines PoCal = Point of Calculation

Table 7-6. Maximum Groundwater Concentration and Point of Calculation of the Individual Sources 200 meters from Waste Management Area A-AX during the Compliance and Sensitivity/Uncertainty Time Period.

Individual Source	Technetium-99 Nominal K_d value: 0 mL/g			Iodine-129 Nominal K_d value: 0.2 mL/g		
	Point of Calculation of Maximum Concentration	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration	Point of Calculation of Maximum Concentration	Maximum Concentration during 10,000-year Sensitivity/Uncertainty Time Frame (pCi/L)	Years after Closure of Maximum Concentration
241-A-101	PoCal 05	5	2,065	PoCal 05	0.0002	8,770
241-A-102	PoCal 05	5	2,125	PoCal 05	0.0001	9,000
241-A-103	PoCal 04	4	2,090	PoCal 04	0.00003	8,770
241-A-104	PoCal 05	20	2,130	PoCal 05	0.0004	8,820
241-A-105	PoCal 05	24	2,220	PoCal 05	0.00007	9,040
241-A-106	PoCal 05	7	2,115	PoCal 05	0.0001	8,790
A Farm AE&P	PoCal 05	0.002	1,940	PoCal 05	0.0006	7,920
241-AX-101	PoCal 09	2	2,445	PoCal 09	0.00005	1,0000
241-AX-102	PoCal 08	0.5	2,400	PoCal 08	0.00004	10,000
241-AX-103	PoCal 09	1	2,475	PoCal 09	0.00004	10,000
241-AX-104	PoCal 08	7	2,460	PoCal 08	0.000003	10,000
AX Farm AE&P	PoCal 08	0.0004	2,125	PoCal 08	6E-08	8,920

AE&P = Ancillary Equipment and Pipelines   PoCal = Point of Calculation

Table 7-7. Maximum Groundwater Concentration of Technetium-99 from Each Source during the Sensitivity/Uncertainty Time Frame at the Points of Calculation at the Fence Line of Waste Management Area A-AX.

Fence Line of Waste Management Area A-AX	PoCal 1	PoCal 1	PoCal 2	PoCal 2	PoCal 3	PoCal 3	PoCal 4	PoCal 4	PoCal 5	PoCal 5	PoCal 6	PoCal 6
	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)
Total	2,120	6	2,130	26	2,145	76	2,160	110	2,170	73	2,325	29
241-A-101	2,060	2	2,060	4	2,060	8	2,065	6	2,065	3	2,060	0.6
241-A-102	2,120	1	2,120	4	2,125	9	2,125	8	2,125	3	2,125	0.4
241-A-103	2,085	0.6	2,085	3	2,090	8	2,090	6	2,090	1	2,090	0.1
241-A-104	2,130	2	2,130	7	2,130	21	2,130	34	2,130	26	2,130	9
241-A-105	2,215	1	2,215	6	2,220	24	2,220	43	2,220	31	2,220	9
241-A-106	2,115	0.2	2,115	1	2,120	7	2,115	13	2,115	9	2,110	2
241-AX-101	2,420	2E-07	2,420	2E-06	2,420	0.00003	2,420	0.0004	2,420	0.006	2,420	0.1
241-AX-102	2,380	9E-07	2,380	0.00001	2,380	0.0001	2,380	0.002	2,380	0.03	2,390	0.4
241-AX-103	2,460	1E-06	2,460	0.00001	2,460	0.0002	2,460	0.002	2,465	0.03	2,465	0.4
241-AX-104	2,450	0.00007	2,450	0.0008	2,450	0.01	2,450	0.1	2,450	1	2,455	8
A Farm AE&P	1,975	0.0007	1,955	0.002	1,935	0.003	1,935	0.003	1,945	0.002	1,965	0.0008
AX Farm AE&P	2,145	7E-09	2,140	8E-08	2,140	9E-07	2,135	9E-06	2,125	0.00007	2,105	0.0004

Fence Line of Waste Management Area A-AX	PoCal 7	PoCal 7	PoCal 8	PoCal 8	PoCal 9	PoCal 9	PoCal 10	PoCal 10	PoCal 11	PoCal 11	PoCal 12	PoCal 12
	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)	Years After Closure	Maximum ^{99}Tc Concentration (pCi/L)
Total	2,445	24	2,455	17	2,460	4	2,460	0.5	2,465	0.05	2,465	0.005
241-A-101	2,060	0.08	2,060	0.009	2,060	0.0008	2,060	0.00006	2,060	6E-06	2,060	6E-07
241-A-102	2,125	0.05	2,125	0.004	2,125	0.0003	2,125	0.00002	2,125	2E-06	2,125	2E-07
241-A-103	2,085	0.01	2,085	0.0007	2,085	0.00005	2,085	4E-06	2,085	3E-07	2,085	3E-08
241-A-104	2,130	2	2,130	0.2	2,130	0.02	2,130	0.002	2,130	0.0002	2,130	0.00002
241-A-105	2,220	1	2,215	0.1	2,215	0.01	2,215	0.001	2,215	0.00009	2,215	9E-06
241-A-106	2,110	0.2	2,110	0.01	2,105	0.001	2,105	0.00007	2,105	6E-06	2,105	6E-07
241-AX-101	2,435	2	2,450	6	2,450	2	2,445	0.1	2,440	0.01	2,440	0.0009
241-AX-102	2,400	2	2,400	0.6	2,395	0.05	2,390	0.003	2,390	0.0003	2,390	0.00002
241-AX-103	2,475	2	2,475	3	2,475	1	2,480	0.2	2,475	0.02	2,475	0.002
241-AX-104	2,460	15	2,460	7	2,455	1	2,455	0.1	2,455	0.01	2,455	0.001
A Farm AE&P	1,980	0.0002	1,990	0.00002	1,995	3E-06	2,000	2E-07	2,005	3E-08	2,010	3E-09
AX Farm AE&P	2,110	0.0007	2,130	0.0007	2,150	0.0004	2,170	0.00009	2,185	0.00001	2,190	1E-06

AE&P = ancillary equipment and pipelines

Table 7-8. Maximum Groundwater Concentration of Technetium-99 from Each Source during the Sensitivity/Uncertainty Time Frame at the Points of Calculation 100 meters from Waste Management Area A-AX.

Fence Line of Waste Management Area A-AX	PoCal 1 Years After Closure	PoCal 1 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 2 Years After Closure	PoCal 2 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 3 Years After Closure	PoCal 3 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 4 Years After Closure	PoCal 4 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 5 Years After Closure	PoCal 5 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 6 Years After Closure	PoCal 6 Maximum ^{99}Tc Concentration (pCi/L)
Total	2,130	6	2,140	19	2,145	44	2,155	71	2,170	77	2,210	56
241-A-101	2,060	1	2,060	3	2,065	5	2,065	6	2,065	5	2,065	2
241-A-102	2,125	1	2,125	3	2,125	5	2,125	7	2,125	5	2,125	3
241-A-103	2,085	0.6	2,090	2	2,090	4	2,090	5	2,090	4	2,090	2
241-A-104	2,130	2	2,130	5	2,130	13	2,130	21	2,130	24	2,130	18
241-A-105	2,220	1	2,220	5	2,220	14	2,220	25	2,220	30	2,220	21
241-A-106	2,120	0.3	2,120	1	2,120	4	2,115	7	2,115	9	2,115	6
241-AX-101	2,430	0.00002	2,430	0.0002	2,430	0.001	2,435	0.01	2,435	0.07	2,440	0.4
241-AX-102	2,385	0.00004	2,390	0.0004	2,390	0.003	2,390	0.02	2,395	0.09	2,395	0.3
241-AX-103	2,470	0.00005	2,470	0.0004	2,470	0.003	2,470	0.02	2,470	0.1	2,475	0.5
241-AX-104	2,455	0.001	2,455	0.01	2,455	0.08	2,455	0.4	2,455	2	2,455	5
A Farm AE&P	1,965	0.0005	1,950	0.001	1,945	0.002	1,940	0.003	1,940	0.002	1,945	0.002
AX Farm AE&P	2,130	1E-07	2,130	7E-07	2,125	4E-06	2,125	0.00002	2,120	0.00008	2,115	0.0002
Fence Line of Waste Management Area A-AX	**PoCal 7 Years After Closure**	**PoCal 7 ^{99}Tc Concentration (pCi/L)**	**PoCal 8 Years After Closure**	**PoCal 8 ^{99}Tc Concentration (pCi/L)**	**PoCal 9 Years After Closure**	**PoCal 9 ^{99}Tc Concentration (pCi/L)**	**PoCal 10 Years After Closure**	**PoCal 10 ^{99}Tc Concentration (pCi/L)**	**PoCal 11 Years After Closure**	**PoCal 11 ^{99}Tc Concentration (pCi/L)**	**PoCal 12 Years After Closure**	**PoCal 12 ^{99}Tc Concentration (pCi/L)**
Total	2,350	32	2,425	19	2,450	10	2,455	3	2,460	0.6	2,460	0.08
241-A-101	2,065	0.8	2,065	0.2	2,060	0.03	2,060	0.004	2,060	0.0004	2,060	0.00003
241-A-102	2,125	0.8	2,125	0.2	2,125	0.02	2,125	0.002	2,125	0.0002	2,125	0.00002
241-A-103	2,090	0.4	2,090	0.07	2,090	0.008	2,090	0.0007	2,090	0.00005	2,090	4E-06
241-A-104	2,130	8	2,130	3	2,130	0.5	2,130	0.07	2,130	0.008	2,130	0.0008
241-A-105	2,220	9	2,220	3	2,220	0.5	2,220	0.05	2,220	0.006	2,220	0.0005
241-A-106	2,115	2	2,115	0.5	2,110	0.08	2,110	0.008	2,110	0.0007	2,110	0.00006
241-AX-101	2,445	1	2,445	2	2,450	2	2,450	0.9	2,450	0.2	2,445	0.03
241-AX-102	2,400	0.7	2,400	0.7	2,400	0.4	2,400	0.08	2,400	0.01	2,395	0.001
241-AX-103	2,475	1	2,475	2	2,475	2	2,475	0.7	2,480	0.2	2,480	0.03
241-AX-104	2,460	9	2,460	8	2,460	4	2,460	1	2,455	0.2	2,455	0.03
A Farm AE&P	1,955	0.0007	1,965	0.0002	1,970	0.00005	1,980	6E-06	1,985	8E-07	1,990	8E-08
AX Farm AE&P	2,120	0.0004	2,125	0.0005	2,140	0.0004	2,150	0.0002	2,160	0.00006	2,170	0.00001

AE&P = ancillary equipment and pipelines

1

Table 7-9. Maximum Groundwater Concentration of Technetium-99 from Each Source during the Sensitivity/Uncertainty Time Frame at the Points of Calculation 200 meters from Waste Management Area A-AX.

Fence Line of Waste Management Area A-AX	PoCal 1 Years After Closure	PoCal 1 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 2 Years After Closure	PoCal 2 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 3 Years After Closure	PoCal 3 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 4 Years After Closure	PoCal 4 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 5 Years After Closure	PoCal 5 Maximum ^{99}Tc Concentration (pCi/L)	PoCal 6 Years After Closure	PoCal 6 Maximum ^{99}Tc Concentration (pCi/L)
Total	2,140	7	2,145	17	2,150	35	2,155	54	2,165	66	2,185	64
241-A-101	2,060	1	2,065	2	2,065	4	2,065	5	2,065	5	2,065	4
241-A-102	2,125	1	2,125	2	2,125	4	2,125	5	2,125	5	2,125	4
241-A-103	2,090	0.7	2,090	2	2,090	3	2,090	4	2,090	4	2,090	3
241-A-104	2,130	2	2,130	5	2,130	10	2,130	16	2,130	20	2,135	20
241-A-105	2,220	2	2,220	5	2,220	11	2,220	19	2,220	24	2,220	24
241-A-106	2,120	0.5	2,120	1	2,120	3	2,120	5	2,115	7	2,115	7
241-AX-101	2,435	0.0002	2,435	0.001	2,435	0.006	2,440	0.03	2,440	0.1	2,440	0.3
241-AX-102	2,390	0.0003	2,390	0.002	2,395	0.008	2,395	0.03	2,395	0.09	2,395	0.2
241-AX-103	2,470	0.0004	2,470	0.002	2,470	0.01	2,470	0.04	2,475	0.1	2,475	0.3
241-AX-104	2,455	0.009	2,455	0.04	2,455	0.2	2,455	0.6	2,455	1	2,455	3
A Farm AE&P	1,955	0.0004	1,950	0.0009	1,945	0.002	1,940	0.002	1,940	0.002	1,940	0.002
AX Farm AE&P	2,125	5E-07	2,125	2E-06	2,120	9E-06	2,120	0.00003	2,120	0.00007	2,120	0.0002
Fence Line of Waste Management Area A-AX	**PoCal 7 Years After Closure**	**PoCal 7 Maximum ^{99}Tc Concentration (pCi/L)**	**PoCal 8 Years After Closure**	**PoCal 8 Maximum ^{99}Tc Concentration (pCi/L)**	**PoCal 9 Years After Closure**	**PoCal 9 Maximum ^{99}Tc Concentration (pCi/L)**	**PoCal 10 Years After Closure**	**PoCal 10 Maximum ^{99}Tc Concentration (pCi/L)**	**PoCal 11 Years After Closure**	**PoCal 11 Maximum ^{99}Tc Concentration (pCi/L)**	**PoCal 12 Years After Closure**	**PoCal 12 Maximum ^{99}Tc Concentration (pCi/L)**
Total	2,230	50	2,330	30	2,410	14	2,440	6	2,450	2	2,455	0.6
241-A-101	2,065	2	2,065	0.9	2,065	0.2	2,065	0.04	2,065	0.008	2,065	0.001
241-A-102	2,125	3	2,125	1	2,125	0.2	2,125	0.04	2,125	0.007	2,125	0.0009
241-A-103	2,090	2	2,090	0.6	2,090	0.1	2,090	0.02	2,090	0.003	2,090	0.0003
241-A-104	2,135	15	2,130	8	2,130	2	2,130	0.5	2,130	0.1	2,130	0.02
241-A-105	2,220	18	2,220	9	2,220	2	2,220	0.5	2,220	0.1	2,220	0.02
241-A-106	2,115	5	2,115	2	2,115	0.6	2,115	0.1	2,115	0.02	2,110	0.003
241-AX-101	2,445	0.7	2,445	1	2,445	2	2,450	1	2,450	0.5	2,450	0.2
241-AX-102	2,395	0.4	2,400	0.5	2,400	0.4	2,400	0.2	2,400	0.07	2,400	0.02
241-AX-103	2,475	0.7	2,475	1	2,475	1	2,475	0.9	2,475	0.4	2,480	0.1
241-AX-104	2,460	5	2,460	7	2,460	5	2,460	2	2,460	0.9	2,460	0.2
A Farm AE&P	1,945	0.001	1,950	0.0007	1,955	0.0002	1,965	0.00005	1,970	0.00001	1,975	2E-06
AX Farm AE&P	2,120	0.0003	2,125	0.0004	2,135	0.0004	2,140	0.0002	2,150	0.0001	2,155	0.00004

AE&P = ancillary equipment and pipelines

Table 7-10. Maximum Groundwater Concentration of Iodine-129 from Each Source during the Sensitivity/Uncertainty Time Frame at the Points of Calculation at the Fence Line of Waste Management Area A-AX.

Fence Line of Waste Management Area A-AX	PoCal 1 Years After Closure	PoCal 1 Maximum ^{129}I Concentration (pCi/L)	PoCal 2 Years After Closure	PoCal 2 Maximum ^{129}I Concentration (pCi/L)	PoCal 3 Years After Closure	PoCal 3 Maximum ^{129}I Concentration (pCi/L)	PoCal 4 Years After Closure	PoCal 4 Maximum ^{129}I Concentration (pCi/L)	PoCal 5 Years After Closure	PoCal 5 Maximum ^{129}I Concentration (pCi/L)	PoCal 6 Years After Closure	PoCal 6 Maximum ^{129}I Concentration (pCi/L)
Total	8,360	0.0003	8,320	0.0009	8,330	0.002	8,370	0.002	8,390	0.001	8,510	0.0005
241-A-101	8,740	0.00006	8,760	0.0002	8,770	0.0003	8,770	0.0002	8,770	0.0001	8,770	0.00002
241-A-102	8,960	0.00002	8,980	0.00008	9,000	0.0002	9,010	0.0001	9,010	0.00005	9,010	8E-06
241-A-103	8,740	4E-06	8,750	0.00002	8,770	0.00005	8,780	0.00004	8,790	9E-06	8,790	9E-07
241-A-104	8,810	0.00004	8,820	0.0002	8,830	0.0005	8,830	0.0007	8,820	0.0006	8,810	0.0002
241-A-105	9,030	3E-06	9,040	0.00002	9,040	0.00007	9,040	0.0001	9,030	0.00009	9,020	0.00003
241-A-106	8,800	2E-06	8,800	0.00002	8,800	0.00009	8,790	0.0002	8,780	0.0001	8,760	0.00002
241-AX-101	10,000	7E-12	10,000	7E-11	10,000	9E-10	10,000	1E-08	10,000	2E-07	10,000	4E-06
241-AX-102	10,000	7E-11	10,000	8E-10	10,000	1E-08	10,000	2E-07	10,000	2E-06	10,000	0.00003
241-AX-103	10,000	3E-11	10,000	4E-10	10,000	5E-09	10,000	7E-08	10,000	9E-07	10,000	0.00001
241-AX-104	10,000	4E-11	10,000	4E-10	10,000	5E-09	10,000	6E-08	10,000	7E-07	10,000	4E-06
A Farm AE&P	8,110	0.0002	8,010	0.0005	7,910	0.0008	7,890	0.0008	7,920	0.0005	8,000	0.0002
AX Farm AE&P	9,070	1E-12	9,070	1E-11	9,050	1E-10	9,030	1E-09	8,970	1E-08	8,840	7E-08

Fence Line of Waste Management Area A-AX	PoCal 7 Years After Closure	PoCal 7 Maximum ^{129}I Concentration (pCi/L)	PoCal 8 Years After Closure	PoCal 8 Maximum ^{129}I Concentration (pCi/L)	PoCal 9 Years After Closure	PoCal 9 Maximum ^{129}I Concentration (pCi/L)	PoCal 10 Years After Closure	PoCal 10 Maximum ^{129}I Concentration (pCi/L)	PoCal 11 Years After Closure	PoCal 11 Maximum ^{129}I Concentration (pCi/L)	PoCal 12 Years After Closure	PoCal 12 Maximum ^{129}I Concentration (pCi/L)
Total	10,000	0.0003	10,000	0.0003	10,000	0.0001	10,000	0.00001	10,000	1E-06	10,000	1E-07
241-A-101	8,770	3E-06	8,760	3E-07	8,760	3E-08	8,750	2E-09	8,750	2E-10	8,750	2E-11
241-A-102	9,010	8E-07	9,000	7E-08	9,000	6E-09	9,000	4E-10	9,000	4E-11	9,000	3E-12
241-A-103	8,790	7E-08	8,780	5E-09	8,780	3E-10	8,780	2E-11	8,780	2E-12	8,780	2E-13
241-A-104	8,800	0.00004	8,790	5E-06	8,780	5E-07	8,780	5E-08	8,770	5E-09	8,770	5E-10
241-A-105	9,010	4E-06	9,000	4E-07	8,990	3E-08	8,990	3E-09	8,980	2E-10	8,980	2E-11
241-A-106	8,750	2E-06	8,740	2E-07	8,740	2E-08	8,740	1E-09	8,740	9E-11	8,730	8E-12
241-AX-101	10,000	0.00005	10,000	0.0002	10,000	0.00005	10,000	4E-06	10,000	3E-07	10,000	3E-08
241-AX-102	10,000	0.0001	10,000	0.00005	10,000	4E-06	10,000	3E-07	10,000	2E-08	10,000	2E-09
241-AX-103	10,000	0.00006	10,000	0.00009	10,000	0.00004	10,000	6E-06	10,000	6E-07	10,000	7E-08
241-AX-104	10,000	8E-06	10,000	4E-06	10,000	6E-07	10,000	6E-08	10,000	6E-09	10,000	6E-10
A Farm AE&P	8,080	0.00004	8,160	5E-06	8,220	6E-07	8,280	5E-08	8,330	6E-09	8,380	6E-10
AX Farm AE&P	8,810	1E-07	8,930	1E-07	9,070	7E-08	9,220	1E-08	9,310	2E-09	9,350	2E-10

AE&P = ancillary equipment and pipelines

Table 7-11. Maximum Groundwater Concentration of Iodine-129 from Each Source during the Sensitivity/Uncertainty Time Frame at the Points of Calculation 100 meters from Waste Management Area A-AX.

Fence Line of Waste Management Area A-AX	PoCal 1	PoCal 1	PoCal 2	PoCal 2	PoCal 3	PoCal 3	PoCal 4	PoCal 4	PoCal 5	PoCal 5	PoCal 6	PoCal 6
	Years After Closure	Maximum ^{129}I Concentration (pCi/L)	Years After Closure	Maximum ^{129}I Concentration (pCi/L)	Years After Closure	Maximum ^{129}I Concentration (pCi/L)	Years After Closure	Maximum ^{129}I Concentration (pCi/L)	Years After Closure	Maximum ^{129}I Concentration (pCi/L)	Years After Closure	Maximum ^{129}I Concentration (pCi/L)
Total	8,350	0.0002	8,340	0.0006	8,340	0.001	8,350	0.002	8,380	0.002	8,430	0.001
241-A-101	8,750	0.00004	8,760	0.0001	8,760	0.0002	8,770	0.0002	8,770	0.0002	8,770	0.00009
241-A-102	8,980	0.00002	8,990	0.00005	8,990	0.0001	9,000	0.0001	9,010	0.0001	9,010	0.00005
241-A-103	8,750	4E-06	8,760	0.00001	8,770	0.00003	8,770	0.00003	8,780	0.00003	8,780	0.00001
241-A-104	8,820	0.00003	8,820	0.0001	8,820	0.0003	8,830	0.0005	8,820	0.0005	8,820	0.0004
241-A-105	9,040	4E-06	9,040	0.00001	9,040	0.00004	9,040	0.00007	9,040	0.00008	9,030	0.00006
241-A-106	8,800	4E-06	8,800	0.00002	8,800	0.00006	8,790	0.0001	8,790	0.0001	8,780	0.00008
241-AX-101	10,000	5E-10	10,000	5E-09	10,000	4E-08	10,000	3E-07	10,000	2E-06	10,000	0.00001
241-AX-102	10,000	3E-09	10,000	3E-08	10,000	2E-07	10,000	1E-06	10,000	7E-06	10,000	0.00003
241-AX-103	10,000	1E-09	10,000	1E-08	10,000	9E-08	10,000	6E-07	10,000	3E-06	10,000	0.00001
241-AX-104	10,000	8E-10	10,000	6E-09	10,000	4E-08	10,000	2E-07	10,000	9E-07	10,000	3E-06
A Farm AE&P	8,050	0.0001	8,000	0.0003	7,950	0.0005	7,920	0.0007	7,910	0.0006	7,920	0.0004
AX Farm AE&P	8,990	2E-11	8,980	1E-10	8,960	7E-10	8,930	3E-09	8,900	1E-08	8,880	4E-08
Fence Line of Waste Management Area A-AX	**PoCal 7**	**PoCal 7**	**PoCal 8**	**PoCal 8**	**PoCal 9**	**PoCal 9**	**PoCal 10**	**PoCal 10**	**PoCal 11**	**PoCal 11**	**PoCal 12**	**PoCal 12**
	Years After Closure	**Maximum ^{129}I Concentration (pCi/L)**	**Years After Closure**	**Maximum ^{129}I Concentration (pCi/L)**	**Years After Closure**	**Maximum ^{129}I Concentration (pCi/L)**	**Years After Closure**	**Maximum ^{129}I Concentration (pCi/L)**	**Years After Closure**	**Maximum ^{129}I Concentration (pCi/L)**	**Years After Closure**	**Maximum ^{129}I Concentration (pCi/L)**
Total	8,680	0.0005	9,880	0.0003	10,000	0.0002	10,000	0.00006	10,000	0.00001	10,000	2E-06
241-A-101	8,770	0.00003	8,770	7E-06	8,770	1E-06	8,770	1E-07	8,760	1E-08	8,760	1E-09
241-A-102	9,010	0.00001	9,010	3E-06	9,010	4E-07	9,010	4E-08	9,010	4E-09	9,010	3E-10
241-A-103	8,790	3E-06	8,790	5E-07	8,790	5E-08	8,790	4E-09	8,790	3E-10	8,790	3E-11
241-A-104	8,820	0.0002	8,810	0.00006	8,810	0.00001	8,800	2E-06	8,800	2E-07	8,790	2E-08
241-A-105	9,030	0.00002	9,020	7E-06	9,020	1E-06	9,010	2E-07	9,010	2E-08	9,000	1E-09
241-A-106	8,770	0.00003	8,770	8E-06	8,760	1E-06	8,760	1E-07	8,750	1E-08	8,750	8E-10
241-AX-101	10,000	0.00004	10,000	0.00007	10,000	0.00007	10,000	0.00003	10,000	6E-06	10,000	8E-07
241-AX-102	10,000	0.00005	10,000	0.00006	10,000	0.00003	10,000	7E-06	10,000	1E-06	10,000	1E-07
241-AX-103	10,000	0.00004	10,000	0.00005	10,000	0.00005	10,000	0.00002	10,000	5E-06	10,000	8E-07
241-AX-104	10,000	4E-06	10,000	4E-06	10,000	2E-06	10,000	6E-07	10,000	1E-07	10,000	1E-08
A Farm AE&P	7,960	0.0002	8,000	0.00005	8,040	0.00001	8,090	1E-06	8,130	2E-07	8,170	2E-08
AX Farm AE&P	8,890	7E-08	8,930	8E-08	9,000	7E-08	9,070	3E-08	9,130	9E-09	9,190	2E-09

AE&P = ancillary equipment and pipelines

Table 7-12. Maximum Groundwater Concentration of Iodine-129 from Each Source during the Sensitivity/Uncertainty Time Frame at the Points of Calculation 200 meters from Waste Management Area A-AX.

Fence Line of Waste Management Area A-AX	PoCal 1 Years After Closure	PoCal 1 Maximum ^{129}I Concentration (pCi/L)	PoCal 2 Years After Closure	PoCal 2 Maximum ^{129}I Concentration (pCi/L)	PoCal 3 Years After Closure	PoCal 3 Maximum ^{129}I Concentration (pCi/L)	PoCal 4 Years After Closure	PoCal 4 Maximum ^{129}I Concentration (pCi/L)	PoCal 5 Years After Closure	PoCal 5 Maximum ^{129}I Concentration (pCi/L)	PoCal 6 Years After Closure	PoCal 6 Maximum ^{129}I Concentration (pCi/L)
Total	8,350	0.0002	8,350	0.0005	8,350	0.0009	8,360	0.001	8,370	0.001	8,390	0.001
241-A-101	8,760	0.00004	8,760	0.00007	8,770	0.0001	8,770	0.0002	8,770	0.0002	8,770	0.0001
241-A-102	8,990	0.00002	8,990	0.00004	8,990	0.00007	9,000	0.0001	9,000	0.0001	9,010	0.00008
241-A-103	8,760	4E-06	8,760	0.00001	8,770	0.00002	8,770	0.00003	8,780	0.00003	8,780	0.00002
241-A-104	8,820	0.00004	8,820	0.0001	8,830	0.0002	8,830	0.0004	8,820	0.0004	8,820	0.0004
241-A-105	9,040	5E-06	9,040	0.00001	9,040	0.00003	9,040	0.00005	9,040	0.00007	9,040	0.00007
241-A-106	8,800	7E-06	8,800	0.00002	8,800	0.00004	8,790	0.00008	8,790	0.0001	8,790	0.0001
241-AX-101	10,000	6E-09	10,000	3E-08	10,000	2E-07	10,000	8E-07	10,000	3E-06	10,000	9E-06
241-AX-102	10,000	3E-08	10,000	1E-07	10,000	6E-07	10,000	2E-06	10,000	7E-06	10,000	0.00002
241-AX-103	10,000	1E-08	10,000	6E-08	10,000	3E-07	10,000	1E-06	10,000	3E-06	10,000	9E-06
241-AX-104	10,000	5E-09	10,000	2E-08	10,000	9E-08	10,000	3E-07	10,000	8E-07	10,000	2E-06
A Farm AE&P	8,020	0.0001	7,980	0.0002	7,950	0.0004	7,930	0.0005	7,920	0.0006	7,920	0.0005
AX Farm AE&P	8,950	8E-11	8,940	3E-10	8,920	1E-09	8,910	4E-09	8,900	1E-08	8,900	2E-08

Fence Line of Waste Management Area A-AX	PoCal 7 Years After Closure	PoCal 7 Maximum ^{129}I Concentration (pCi/L)	PoCal 8 Years After Closure	PoCal 8 Maximum ^{129}I Concentration (pCi/L)	PoCal 9 Years After Closure	PoCal 9 Maximum ^{129}I Concentration (pCi/L)	PoCal 10 Years After Closure	PoCal 10 Maximum ^{129}I Concentration (pCi/L)	PoCal 11 Years After Closure	PoCal 11 Maximum ^{129}I Concentration (pCi/L)	PoCal 12 Years After Closure	PoCal 12 Maximum ^{129}I Concentration (pCi/L)
Total	8,450	0.0009	8,660	0.0005	9,540	0.0002	10,000	0.00009	10,000	0.00004	10,000	0.00001
241-A-101	8,770	0.00008	8,770	0.00003	8,770	8E-06	8,770	2E-06	8,770	3E-07	8,770	4E-08
241-A-102	9,010	0.00005	9,010	0.00002	9,010	4E-06	9,010	7E-07	9,010	1E-07	9,010	2E-08
241-A-103	8,780	0.00001	8,790	4E-06	8,790	7E-07	8,790	1E-07	8,790	2E-08	8,790	2E-09
241-A-104	8,820	0.0003	8,820	0.0002	8,820	0.00005	8,810	0.00001	8,810	3E-06	8,810	4E-07
241-A-105	9,040	0.00005	9,030	0.00002	9,030	7E-06	9,020	2E-06	9,020	3E-07	9,020	5E-08
241-A-106	8,780	0.00007	8,780	0.00003	8,780	8E-06	8,770	2E-06	8,770	3E-07	8,760	4E-08
241-AX-101	10,000	0.00002	10,000	0.00004	10,000	0.00005	10,000	0.00003	10,000	0.00002	10,000	5E-06
241-AX-102	10,000	0.00003	10,000	0.00004	10,000	0.00003	10,000	0.00002	10,000	5E-06	10,000	1E-06
241-AX-103	10,000	0.00002	10,000	0.00004	10,000	0.00004	10,000	0.00002	10,000	0.00001	10,000	4E-06
241-AX-104	10,000	3E-06	10,000	3E-06	10,000	3E-06	10,000	1E-06	10,000	4E-07	10,000	1E-07
A Farm AE&P	7,920	0.0004	7,940	0.0002	7,970	0.00005	8,000	0.00001	8,020	3E-06	8,050	4E-07
AX Farm AE&P	8,900	4E-08	8,920	6E-08	8,960	6E-08	9,010	4E-08	9,050	2E-08	9,090	6E-09

AE&P = ancillary equipment and pipelines

7.1.2.1 Comparison of Simulated Vadose Zone Moisture Content and Waste Management Area A-AX Field-Measured Data. The moisture content in the vadose zone underneath WMA A-AX changes in response to changes in the recharge imposed by the surface conditions. This includes an increase in moisture content that occurs during the operations period, and an eventual decrease in moisture content caused by the performance of the surface barrier. The moisture content is also influenced by the presence of the tank structures, which divert the water around the low permeability structures. For the base case, the tank structures are assumed to remain intact for the duration of the analysis.

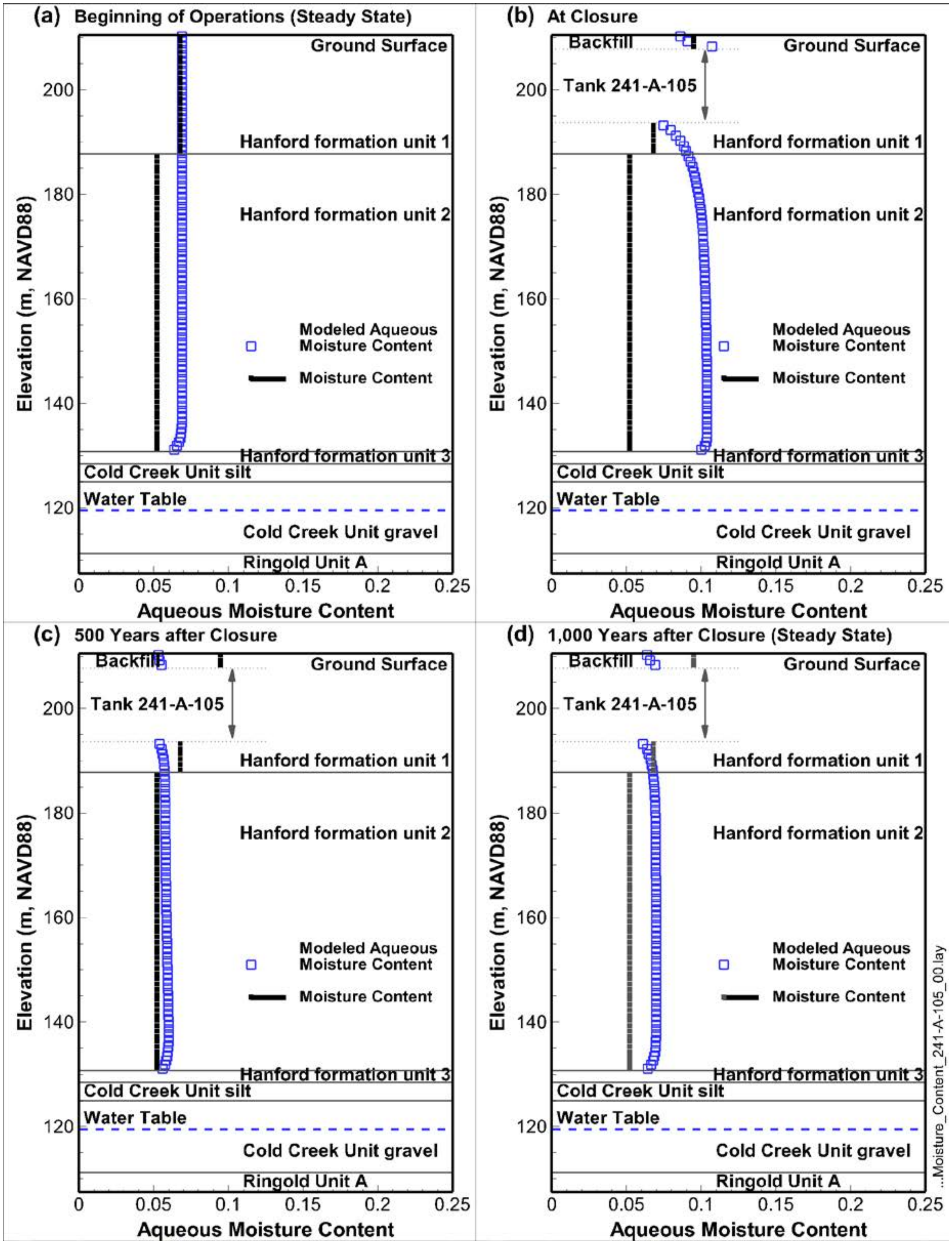
Figure 7-20(a-d) and Figure 7-21(a-d) present the calculated moisture content profile at and around tank 241-A-105 for four times in the evolution of the facility. The figures include the average moisture content values identified in Table A-1 of RPP-ENV-58578 for the corresponding HSUs for the purpose of comparison:

- Backfill samples: 9.50% by volume
- Hanford formation unit 1 samples: 6.80% by volume
- Hanford formation unit 2 samples: 5.23% by volume.

The inclusion of the average moisture content values shown in Figure 7-20(a-d) and Figure 7-21(a-d) does not correspond to the spatial distribution associated with sample or measurement collection depths, but simply corresponds to the HSU of the model cell indicated in the model. Calibration or direct comparison of the model results to the average values is not considered appropriate because the data represent several different measurement locations in WMA A-AX where the data were collected in 2014 (RPP-ENV-58578). The data exhibited considerable variability, ranging from close to zero to as high as 43.2% by volume (RPP-ENV-58578). The inclusion of the average values on Figure 7-20(a-d) and Figure 7-21(a-d) only intends to provide a qualitative indication of the model's representation of the vadose zone moisture profile.

The pre-Hanford profile associated with tank 241-A-105 is shown in Figure 7-20(a), although the tank or tank farm backfill do not appear in this frame of the figure because the frame represents pre-Hanford conditions. This profile provides a reference point for the subsequent behavior of the system in response to changes in the net infiltration rates. The moisture content of the Hanford formation unit 1 sandy gravel (H1) model cells is a uniform value of 0.069, and the moisture content of the Hanford formation unit 2 sand (H2) model cells ranges from 0.064 to 0.069 for the pre-Hanford time period. The moisture content profile at the assumed time of closure and the construction of the surface barrier is shown in Figure 7-20(b). This moisture profile is higher relative to the pre-Hanford profile, ranging from 0.086 to 0.107 in the backfill model cells, from 0.074 to 0.090 in the H1 cells, and from 0.092 to 0.104 in the H2 cells, owing to the elevated net infiltration during the operational period.

Figure 7-20. Moisture Content in the Vadose Zone at Tank 241-A-105 at Four Times of Interest: (a) Pre-Hanford Steady State, (b) Year of Assumed Closure, (c) 500 Years after Assumed Closure, and (d) 1,000 Years after Assumed Closure.



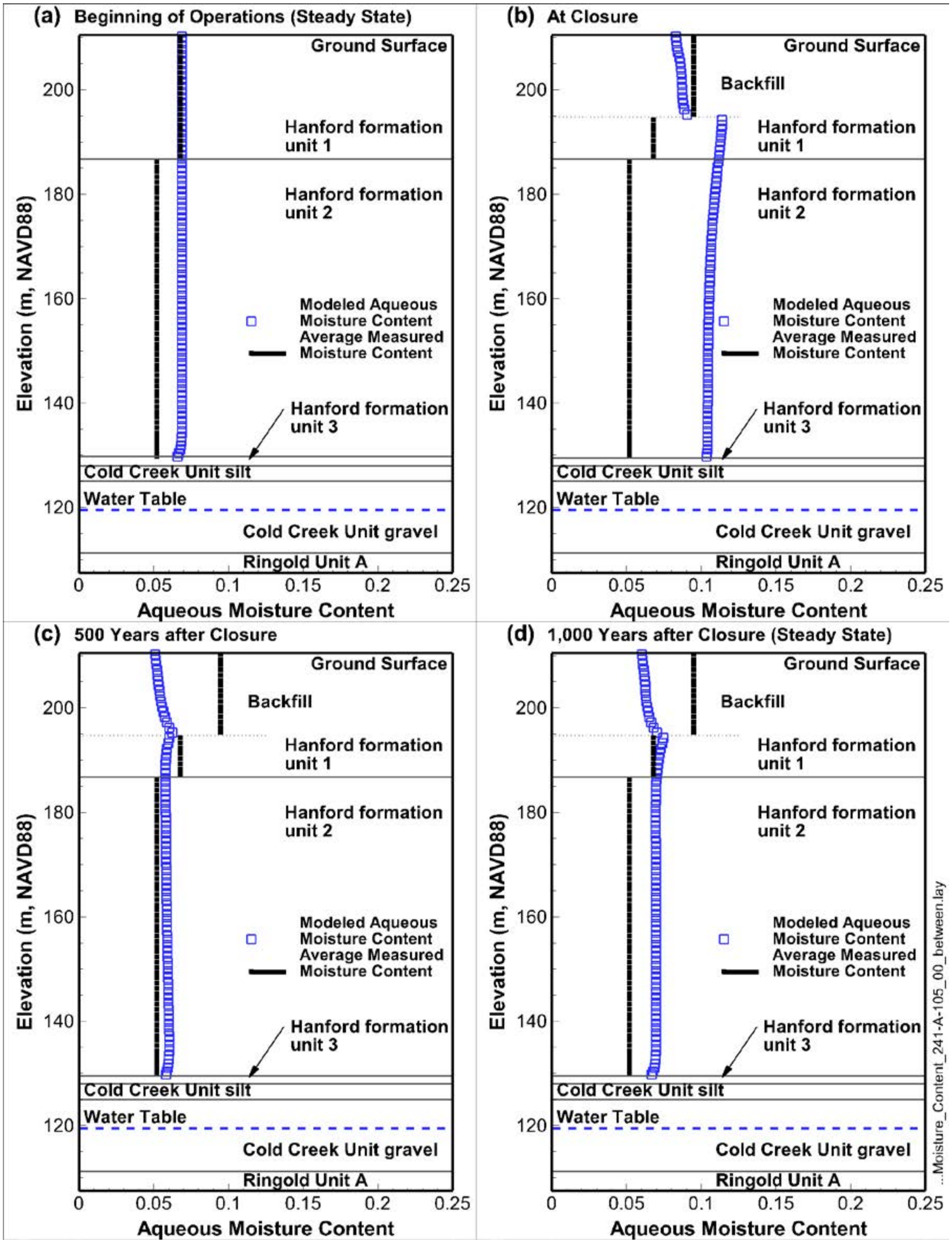
NAVD88 = *North American Vertical Datum of 1988*

The response of the moisture content after 500 years from the assumed construction of the surface barrier is shown in Figure 7-20(c). The moisture content has decreased as the system responds to the lower recharge produced by the surface barrier. The moisture content ranges from 0.053 to 0.055 in the backfill model cells, from 0.054 to 0.057 in the H1 cells, and from 0.056 to 0.060 in the H2 cells. In the base case analysis, the surface barrier is assumed to degrade after 500 years, leading to a return to the pre-Hanford recharge rate. As shown in Figure 7-20(d), by 1,000 years after the assumed closure, the system has re-equilibrated to a steady-state moisture regime, with a moisture content profile similar to the pre-Hanford moisture content distribution shown in Figure 7-20(a) except where the presence of the tank has disrupted the profile. The moisture content ranges from 0.064 to 0.069 in the backfill model cells, from 0.061 to 0.067 in the H1 cells, and from 0.064 to 0.070 in the H2 cells.

The calculated moisture content profile for a location in between four 100-series tanks (241-A-101, 241-A-105, 241-A-102, and 241-A-104) is presented in Figure 7-21. The pre-Hanford profile and range in Hanford H2 Sand moisture content shown in Figure 7-21(a) is almost identical to the profile shown in Figure 7-20(a) because the two locations are so close and the geology is essentially the same. The moisture content in the H1 model cells is a uniform 0.069, but the moisture content in the H2 model cells only ranges from 0.066 to 0.069. Similar to Figure 7-20(a), Figure 7-21(a) provides a reference point for the subsequent behavior of the system in response to changes in the net infiltration rates. The moisture content profile at the assumed time of closure shown in Figure 7-21(b) indicates that the moisture content, ranging from 0.083 to 0.090 in the backfill model cells, from 0.112 to 0.114 in the H1 cells, and from 0.103 to 0.111 in the H2 cells, is elevated compared to both the pre-Hanford profile (Figure 7-21 [a]) and the profile shown in Figure 7-20(b). The increase in moisture content in Figure 7-20(b) compared to Figure 7-21(b) results from the tank umbrella effect that diverts infiltrating water from the tank domes to the area(s) surrounding the tanks.

The response 100 years after assumed closure is shown in Figure 7-21(c). It is almost identical to the response below tank 241-A-105 shown in Figure 7-20(c) because with the surface barrier limiting net infiltration to 0.5 mm/yr (0.02 in./yr), the tank umbrella effect becomes almost inconsequential. The moisture content ranges from 0.051 to 0.062 in the backfill model cells, from 0.058 to 0.060 in the H1 cells and the H2 cells. The moisture content profile 1,000 years after assumed closure (Figure 7-21[d]) appears to be very similar to the pre-Hanford moisture content profile shown in Figure 7-21(a) and Figure 7-20(a). The moisture content ranges from 0.060 to 0.070 in the backfill model cells, from 0.070 to 0.075 in the H1 cells, and from 0.067 to 0.070 in the H2 cells.

Figure 7-21. Moisture Content in the Vadose Zone between Tanks 241 A 105, 241 A 101, 241 A 102, and 241 A 104 at Four Times of Interest: (a) Pre-Hanford Steady State, (b) Year of Assumed Closure, (c) 500 Years after Assumed Closure, and (d) 1,000 Years after Assumed Closure.



NAVD88 = *North American Vertical Datum of 1988*

7.1.2.2 Mass Balance. The mass balance evaluations provide an assessment of the internal consistency and accuracy of the solution of the discretized equations computed in eSTOMP. The mass balance evaluations consist of determining the gains and losses of water and contaminant mass caused by the overall numerical approximation of the hydrogeologic system and the solution techniques within eSTOMP. To evaluate the aqueous mass balance, fluxes from surface files and integrals of the moisture content were checked to verify that the quantities balanced[12]. To evaluate the radionuclide mass balance, the release functions, fluxes from surface files, and integrals of the volumetric concentration were checked to verify that the quantities balanced.

Section 3.4.3.2 identifies the following mass balance checks.

- Steady-state aqueous volume entering and exiting the model domain

  The steady-state aqueous mass balance evaluation consists of summing the aqueous flow [rate] of water through the planes containing the aquifer upon the conclusion of the second step of the steady-state preconditioning. At steady state, the aqueous volume entering and exiting the model domain ought to be equal. As indicated in Table 7-13, there is a discrepancy of about - 3.2 m^3/yr; the negative value indicates that the error involves excess flow leaving the domain. Compared to the overall volume rate of flow, the error is 0.0008%.

- The difference between the aqueous volume that enters and exits the domain and the change in volume remaining within the domain relative to the amount of aqueous volume entering the domain for the period Year 1943 to Year 2050

  The transient aqueous mass balance evaluation for the period Year 1943 to Year 2050 consists of summing the aqueous volume of water that entered and exited the model domain and the change in the moisture content within the model domain, upon the conclusion of the operations step of the modeling. Because of the uneven surface of the ground, the top of the model in the mass balance evaluation is layer 91, which is the lowest layer with a ground surface (i.e., top) recharge boundary condition. The difference between the aqueous volume that entered and exited the model domain ought to equal the change in the integrated moisture content. As indicated in Table 7-14, 4,852,567 m^3 of recharge[13] entered the domain below layer 91, and 41,125,480 m^3 of flow entered the aquifer from the western boundary. Flow exited the aquifer along the east aquifer boundary (41,924,180 m^3), the north aquifer boundary and the layer immediately above the saturated zone (1,500,617 m^3 and 2,335 m^3, respectively), and the south aquifer boundary and the layer immediately above the saturated zone (1,158,395 m^3 and 8,357 m^3, respectively). No volume of water entered or exited the model domain through the other vadose zone boundaries. Summing the flow quantities into the aquifer and subtracting from that sum the flow quantities out of the aquifer indicates that about

[12] Although described as mass balance, the evaluation of water balance involves the calculated volume(s) of water, which is acceptable because the process model is a constant-temperature model and the water density is constant.

[13] The precision expressed in the values does not denote confidence in the quantitative estimates of the real-world system to the indicated level of accuracy, but describes the precision necessary to conduct the mass balance evaluation.

1,384,163 m^3 more of aqueous volume entered the model domain than exited it. The increase in the integrated moisture content is calculated to be 1,384,475 m^3 (Tecplot® integration). There is a discrepancy of about - 312 m^3 between the net flow into the model domain and the increase in the integrated moisture content. The negative value indicates that the error involves excess water in the integrated moisture content value. Compared to the overall volume of water entering the domain, the error is
$100\% \times 312\ m^3 / 45{,}978{,}047\ m^3 = 0.0007\%$.

Table 7-13. Waste Management Area A-AX Three-Dimensional Model Mass Balance Evaluation: Pre-Operations Steady-State Water Balance.

Description of Flux Plane Surface	Surface Orientation	Surface Card Indices	Flow [Rate]of Water through Plane (m^3/yr)*
Horizontal plane near base of vadose zone	bottom	1, 100, 1, 120, 20, 20	2,922.4
Vertical plane one layer above water table at west domain boundary	west	1, 1, 1, 120, 19, 19	0
Vertical plane one layer above water table at east domain boundary	east	100, 100, 1, 120, 19, 19	0
Vertical plane across saturated zone at west domain boundary	west	1, 1, 1, 120, 1, 18	-384,350.3
Vertical plane across saturated zone at east domain boundary	east	100, 100, 1, 120, 1, 18	387,275.9
Vertical plane one layer above water table at north domain boundary	north	1, 100, 120, 120, 19, 19	3.9E-11
Vertical plane one layer above water table at south domain boundary	south	1, 100, 1, 1, 19, 19	6.9E-12
Vertical plane across saturated zone at north domain boundary	north	1, 100, 120, 120, 1, 18	-3.6E-08
Vertical plane across saturated zone at south domain boundary	south	1, 100, 1, 1, 1, 18	5.2E-09
Flow [Rate] into aquifer	All	Not applicable	387,272.7
Flow [Rate] out of domain boundaries	All	Not applicable	387,275.9
Percent Imbalance			0.0008%

*Negative flux indicates that the direction of movement is opposite the surface orientation.
Flow [Rate] into aquifer = 2,922.4 m^3/yr – (-384,350.3 m^3/yr) – (-3.6E-08 m^3/yr) = 387,272.7 m^3/yr.
Flow [Rate] out through domain boundaries = 387,275.9 m^3/yr + 3.9E-11 m^3/yr + 6.9E-12 m^3/yr + 5.2E-09 m^3/yr = 387,275.9 m^3/yr.
Net Flow [Rate] = 387,272.7 m^3/yr – 387,275.9 m^3/yr = - 3.2 m^3/yr; Percent Imbalance = 0.0008%.
Simulation designation: 00ss_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol. File: surface
Mass balance calculation file: surface_mass_balance_ss.xlsx.

Table 7-14. Waste Management Area A-AX Three-Dimensional Model Mass Balance Evaluation: Operations Period Transient Water Balance Years 1943 to 2050.

Description of Flux Plane Surface	Surface Orientation	Surface Card Indices	Cumulative Volume of Water through Plane (m^3)*
Horizontal plane beneath lowest surface boundary condition	bottom	1, 100, 1, 120, 91,91	4,852,567
Vertical plane one layer above water table at west domain boundary	west	1, 1, 1, 120, 19, 19	0
Vertical plane one layer above water table at east domain boundary	east	100, 100, 1, 120, 19, 19	0
Vertical plane across saturated zone at west domain boundary	west	1, 1, 1, 120, 1, 18	-41,125,480
Vertical plane across saturated zone at east domain boundary	east	100, 100, 1, 120, 1, 18	41,924,180
Vertical plane one layer above water table at north domain boundary	north	1, 100, 120, 120, 19, 19	2,335
Vertical plane one layer above water table at south domain boundary	south	1, 100, 1, 1, 19, 19	8,357
Vertical plane across saturated zone at north domain boundary	north	1, 100, 120, 120, 1, 18	1,500,617
Vertical plane across saturated zone at south domain boundary	south	1, 100, 1, 1, 1, 18	1,158,395
Cumulative volume into domain	All	Not applicable	45,978,047
Cumulative volume out of domain boundaries	All	Not applicable	44,593,884
Increase in moisture content	All	Not applicable	1,384,475
Percent Imbalance in overall aqueous volume			0.0007%

*Negative flux indicates that the direction of movement is opposite the surface orientation.
Cumulative flow into domain = 4,852,567 m^3 – (-41,125,480 m^3) = 45,978,047 m^3.
Cumulative flow out through domain boundaries = 41,924,180 m^3 + 2,335 m^3 + 8,357 m^3 + 1,500,617 m^3 + 1,158,395 m^3 = 44,593,884 m^3.
Increase in moisture content = 1,384,475 m^3 (Tecplot® integration: moisture content: K=6 … K = 91 {for plot files loaded "Coordinates Nodal; Values Cell Centered" K=91 corresponds to bottom of layer 91}).
Cumulative net flow = 45,978,047 m^3 - 44,593,884 m^3 = 1,384,163 m^3; Less the increase in moisture content = 1,384,163 m^3 - 1,384,475 m^3 = - 312 m^3. Percent imbalance in overall aqueous volume = 100% * 312 / 45,978,047 = 0.0007%.
Simulation designation: 00ss_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol. File: plot.348.
01op_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol. Files: surface, plot.513.
Mass balance calculation file: surface_mass_balance_op.xlsx.

- The difference between the aqueous volume that enters and exits the domain and the change in volume remaining within the domain for the period Year 2050 to Year 3050 relative to the amount of aqueous volume exiting the domain, and the steady-state aqueous volume entering and exiting the model domain in Year 3050 (1,000 years after assumed closure)

The transient aqueous mass balance evaluation for the period Year 2050 to Year 3050 consists of the same calculations as described previously, except that the calculations are based on the conclusion of the time step of the modeling representing Year 3050. Because of the uneven surface of the ground, the top of the model in the mass balance evaluation is layer 91, which is the lowest layer with a ground surface (i.e., top) recharge boundary condition. The difference between the aqueous volume that entered and exited the model domain ought to equal the change in the integrated moisture content. As indicated in Table 7-15, about 1,387,768 m^3 more water exited the model domain than entered it, and the decrease in the integrated moisture content is 1,384,668 m^3. There is a discrepancy of about – 3,100 m^3; the negative value indicates that the error involves excess water within the model domain. Compared to the overall volume of water exiting the domain, the error is 100% × 3,100 m^3 / 393,408,800 m^3 = 0.0008%.

The steady-state aqueous mass balance evaluation consists of summing the aqueous flow [rate] of water through the planes containing the aquifer upon the conclusion of the time step of the modeling representing Year 3050. As indicated in Table 7-15, there is a discrepancy of about - 3.1 m^3/yr; the negative value indicates that the error involves excess flow leaving the domain. Compared to the overall volume rate of flow, the error is 0.0008%.

- The difference between the mass of ^{99}Tc that enters and exits the domain and the change in mass remaining within the domain for the period Year 2050 to the approximate time that the peak concentration of ^{99}Tc occurs at the 100-m PoCal (Year 4220, 2,170 years after assumed closure)

The transient ^{99}Tc mass balance evaluation for the Year 4220 consists of (1) integrating and summing the ^{99}Tc mass release functions to Year 4220 (2,170 years after assumed closure), (2) calculating the ^{99}Tc mass within the model domain upon the conclusion of the time step of the modeling representing Year 4220, and (3) calculating the ^{99}Tc mass to exit the model domain upon the conclusion of that time step. The difference between the ^{99}Tc mass release function summation and the ^{99}Tc mass that exited the model domain ought to equal the increase in the ^{99}Tc mass within the model domain. As indicated in Table 7-16, the summation of the mass release functions indicates that about 495.9796 g ^{99}Tc release into the model domain from Year 2050 to Year 4220. The mass of ^{99}Tc remaining within the model domain is calculated to be 93.1364 g, and the mass exiting the model domain is calculated to be 403.5268 g. The discrepancy between the mass of ^{99}Tc entering, exiting, and remaining with the model domain is -0.684 g, which is -0.14% of the summation of the ^{99}Tc mass release functions.

- The difference between the mass of ^{99}Tc and ^{129}I that enters and exits the domain and the change in mass remaining within the domain for the period Year 2050 to Year 12050 (10,000 years after assumed closure)

Table 7-15. Waste Management Area A-AX Three-Dimensional Model Mass Balance Evaluation: Post-Closure Period Transient and Steady-State Water Balance Years 2050 to 3050.

Description of Flux Plane Surface	Surface Orientation	Surface Card Indices	Flow [Rate] of Water through Plane (m^3/yr)*	Cumulative Volume of Water through Plane (m^3)*
Horizontal plane beneath lowest surface boundary condition	bottom	1, 100, 1, 120, 91,91	2,922.45	4,963,353
Vertical plane one layer above water table at west domain boundary	west	1, 1, 1, 120, 19, 19	0	0
Vertical plane one layer above water table at east domain boundary	east	100, 100, 1, 120, 19, 19	0	0
Vertical plane across saturated zone at west domain boundary	west	1, 1, 1, 120, 1, 18	-384,350.3	-384,350,300
Vertical plane across saturated zone at east domain boundary	east	100, 100, 1, 120, 1, 18	392,807.9	393,408,800
Vertical plane one layer above water table at north domain boundary	north	1, 100, 120, 120, 19, 19	-4.17	-1,708
Vertical plane one layer above water table at south domain boundary	south	1, 100, 1, 1, 19, 19	-39.73	-26,436
Vertical plane across saturated zone at north domain boundary	north	1, 100, 120, 120, 1, 18	-3,438.42	-1,895,476
Vertical plane across saturated zone at south domain boundary	south	1, 100, 1, 1, 1, 18	-2,049.74	-783,759
Cumulative volume into domain	All	N/A	392,804.8	392,021,032
Cumulative volume out of domain boundaries	All	N/A	392,807.9	393,408,800
Decrease in moisture content	All	N/A	N/A	1,384,668
Percent Imbalance			0.0008%	0.0008%

*Negative flux indicates that the direction of movement is opposite the surface orientation.

Steady-state evaluation (Year 3050 or 1,000 years after closure)

Flow [Rate] into aquifer = 2,922.44 – (-384,350.30) – (-4.17) – (-39.73) – (-3,438.42) – (-2,049.74) = 392,804.8

Flow [Rate] out through domain boundaries = 392,807.9

Net Flow [Rate] = 392,804.8 – 392,807.9 = 3.1 m^3/yr; Percent imbalance = 0.0008%.

Transient evaluation (Year 2050 to Year 3050 or 0 to 1,000 years after closure)

Cumulative flow into domain = 4,963,353 m^3 – (-384,350,300 m^3) – (-1,708 m^3) – (-26,436 m^3) – (-1,895,476 m^3) – (-783,759 m^3) = 392,021,032 m^3

Cumulative Flow out through domain boundaries = 393,408,800 m^3.

Decrease in moisture content = 1,384,668 m^3 (Tecplot® Integration: moisture content: K=6 … K = 91 {For plot files loaded "Coordinates Nodal; Values Cell Centered" K=91 corresponds to bottom of layer 91})

Net Cumulative Flow = 392,021,032 m^3 - 393,408,800 m^3 = -1,387,768 m^3; Plus the decrease in moisture content = -1,387,768 m^3 + 1,384,668 m^3 = -3,100 m^3. Percent imbalance in volume = 0.0008%.

Simulation designation: 02pc_tct_03_rch_02_sat_03_bcs091_ccu_18_e_p_t. Files: mass_balance_flux_planes.srf, plot.513, plot.996, Tc99_mass_balance.xlsx

N/A = not applicable

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Table 7-16. Waste Management Area A-AX Three-Dimensional Model Mass Balance Evaluation: Post-Closure Period Transient Technetium-99 Balance Year 4220 (2,170 Years after Closure).

^{99}Tc Source	^{99}Tc Mass Released from Source (g)	^{99}Tc Mass in Domain (g)	^{99}Tc Mass Exiting East Surface (g)	^{99}Tc Mass Exiting North Surface (g)	^{99}Tc Mass Exiting South Surface (g)	^{99}Tc Mass Balance	
						(g)	(%)
241-A-101	28.1834	21.1146	7.1102	2E-09	2E-12	-0.041	-0.15%
241-A-102	31.4404	24.5390	6.9482	2E-09	4E-13	-0.047	-0.15%
241-A-103	22.7973	17.3982	5.4330	1E-09	1E-13	-0.034	-0.15%
241-A-104	133.1445	104.1920	29.1453	2E-08	1E-12	-0.193	-0.14%
241-A-105	157.2466	128.9730	28.4954	2E-08	-8E-13	-0.222	-0.14%
241-A-106	40.9605	31.7738	9.2474	5E-09	-2E-13	-0.061	-0.15%
241-AX-101	14.4152	13.1378	1.2931	1E-08	2E-22	-0.016	-0.11%
241-AX-102	3.9176	3.5247	0.3974	2E-09	1E-21	-0.004	-0.11%
241-AX-103	12.277	11.3482	0.9411	8E-09	1E-21	-0.012	-0.10%
241-AX-104	51.5912	47.5239	4.1209	2E-08	-4E-13	-0.054	-0.10%
A Farm AE&P	0.0048	0.0010	0.0038	2E-12	4E-15	0.000	0%
AX Farm AE&P	0.0011	0.0005	0.0006	5E-12	3E-23	0.000	0%
Total	495.9796	403.5268	93.1364	8E-08	2E-12	-0.684	-0.14%

*Negative mass exiting quantities indicate that the direction of movement is opposite the surface orientation.

AE&P = ancillary equipment and pipelines

Simulation designations	Files
02pc_tct_03_rch_02_sat_03_bcs091_tc99_a_102_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_ax101_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_b_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_c_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_d_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_tc99_e_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_tc99_a_pip_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_tc99_axpip_inv_06_ccu_18_aqc25_e_p_t_z	output, water_balance_and_boundary_flux.srf, Tc99_mass_balance.xlsx

The transient ^{99}Tc and ^{129}I mass balance evaluations for Year 12050 consist of the same calculations as described previously, except that the calculations are based on the conclusion of the time step of the modeling representing Year 12050. As indicated in Table 7-17, the summation of the mass release functions indicates that about 1,712.8743 g ^{99}Tc release into the model domain from Year 2050 to Year 12050. The mass of ^{99}Tc remaining within the model domain is calculated to be 179.4439 g, and the mass exiting the model domain is calculated to be 1,533.399 g. The discrepancy between the mass of ^{99}Tc entering, exiting, and remaining with the model domain is 0.032 g, which is 0.002% of the summation the ^{99}Tc mass release functions.

Table 7-17. Waste Management Area A-AX Three-Dimensional Model Mass Balance Evaluation: Post-Closure Period Transient Technetium-99 Balance Year 12050 (10,000 Years after Closure).

^{99}Tc Source	^{99}Tc Mass Released from Source (g)	^{99}Tc Mass in Domain (g)	^{99}Tc Mass Exiting East Surface (g)	^{99}Tc Mass Exiting North Surface (g)	^{99}Tc Mass Exiting South Surface (g)	^{99}Tc Mass Balance	
						(g)	(%)
241-A-101	89.2157	7.7334	81.4755	3E-08	2E-11	0.007	0.01%
241-A-102	99.5252	8.9477	90.5706	3E-08	3E-12	0.007	0.01%
241-A-103	72.1657	6.3624	65.7981	2E-08	4E-13	0.005	0.01%
241-A-104	453.2899	43.5972	409.6764	3E-07	8E-12	0.016	0.00%
241-A-105	552.9447	57.2843	495.6523	4E-07	3E-13	0.008	0.00%
241-A-106	129.6605	11.6013	118.0494	8E-08	-2E-13	0.010	0.01%
241-AX-101	55.4274	7.6487	47.7826	7E-07	1E-20	-0.004	-0.01%
241-AX-102	15.0635	2.0393	13.0252	1E-07	5E-20	-0.001	-0.01%
241-AX-103	47.206	6.6178	40.5914	6E-07	8E-20	-0.003	-0.01%
241-AX-104	198.3699	27.6118	170.7715	1E-06	-3E-13	-0.013	-0.01%
A Farm AE&P	0.0047	0.0000	0.0047	3E-12	7E-15	0.000	0%
AX Farm AE&P	0.0011	0.0000	0.0011	1E-11	7E-23	0.000	0%
Total	1712.8743	179.4439	1533.399	3E-06	3E-11	0.032	0.002%

*Negative mass exiting quantities indicate that the direction of movement is opposite the surface orientation.

AE&P = ancillary equipment and pipelines

Simulation designations	Files
02pc_tct_03_rch_02_sat_03_bcs091_tc99_a_102_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_ax101_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_b_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_c_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_tc99_d_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_tc99_e_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_tc99_a_pip_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_tc99_axpip_inv_06_ccu_18_aqc25_e_p_t_z	output, water_balance_and_boundary_flux.srf, Tc99_mass_balance.xlsx

As indicated in Table 7-18, the summation of the mass release functions indicates that about 2.9358 g ^{129}I release into the model domain from Year 2050 to Year 12050. The mass of ^{129}I remaining within the model domain is calculated to be 1.4270 g, and the mass exiting the model domain is calculated to be 1.5091 g. The discrepancy between the mass of ^{129}I entering, exiting, and remaining with the model domain is 0.0002 g, which is -0.01% of the summation the ^{129}I mass release functions.

Table 7-18. Waste Management Area A-AX Three-Dimensional Model Mass Balance Evaluation: Post-Closure Period Transient Iodine-129 Balance Year 12050 (10,000 Years after Closure).

^{129}I Source	^{129}I Mass Released from Source (g)	^{129}I Mass in Domain (g)	^{129}I Mass Exiting East Surface (g)	^{129}I Mass Exiting North Surface (g)	^{129}I Mass Exiting South Surface (g)	^{129}I Mass Balance	
						(g)	(%)
241-A-101	0.3184	0.1578	0.1607	6E-11	4E-14	-0.0001	-0.03%
241-A-102	0.1863	0.0990	0.0874	3E-11	2E-15	-0.0001	-0.05%
241-A-103	0.0466	0.0231	0.0235	6E-12	2E-16	0.0000	0.00%
241-A-104	0.8817	0.4444	0.4377	3E-10	9E-15	-0.0004	-0.05%
241-A-105	0.1312	0.0705	0.0607	4E-11	3E-16	0.0000	0.00%
241-A-106	0.1849	0.0922	0.0928	5E-11	1E-16	-0.0001	-0.05%
241-AX-101	0.2216	0.1828	0.0389	5E-10	4E-24	-0.0001	-0.05%
241-AX-102	0.1589	0.1283	0.0306	2E-10	8E-23	0.0000	0.00%
241-AX-103	0.1787	0.1517	0.0271	3E-10	4E-23	-0.0001	-0.06%
241-AX-104	0.0140	0.0118	0.0023	1E-11	5E-23	-0.0001	-0.71%
A Farm AE&P	0.6135	0.0654	0.5473	3E-10	6E-13	0.0008	0.13%
AX Farm AE&P	0.0001	0.0000	0.0001	8E-13	9E-25	0.0000	0.00%
Total	2.9358	1.4270	1.5091	2E-09	6E-13	-0.0002	-0.01%

*Negative mass exiting quantities indicate that the direction of movement is opposite the surface orientation.

AE&P = ancillary equipment and pipelines

Simulation designations	Files
02pc_tct_03_rch_02_sat_03_bcs091_i129_a_102_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_i129_ax101_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_i129_b_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_i129_c_inv_06_ccu_18_aqc25_e_p_t_z 02pc_tct_03_rch_02_sat_03_bcs091_i129_d_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_i129_e_inv_06_ccu_18_aqc25_e_p_t_z. 02pc_tct_03_rch_02_sat_03_bcs091_i129_f_inv_06_ccu_18_aqc25_e_p_t_z.	output, water_balance_and_boundary_flux.srf, I129_mass_balance.xlsx

7.1.2.3 Numerical Solution Stability and Numerical Dispersion. The numerical solution stability and numerical dispersion evaluations involve estimating the Peclet numbers in the vadose zone and aquifer, and conducting simulations with different Courant limits imposed on the time steps. For the WMA A-AX process model, the maximum Peclet in the H1 and H2 vadose zone during the highly transient period that occurs within 100 years from the assumed closure date is estimated to be

$$Pe_{max} = \frac{1.1\,\frac{m}{yr} * 1\text{ m}}{\left(0.25\text{ m} * 1.1\,\frac{m}{yr} + 0.078894\ m^2/\text{yr}\right)} = 3.1 \qquad (7\text{-}1)$$

assuming Δz = a nominal 1 m, v_{max} = 1.1 m/yr (as determined from the A Farm and AX Farm non-tank representative flow field tables for Darcy flux and moisture content in Appendix D of RPP-RPT-60885[14]), α_L = 0.25 m (for sand dominated HSUs) and D* = 2.5×10^{-9} m^2/s or 0.078894 m^2/yr). After 100 years, the maximum Peclet throughout the vadose zone is estimated to be

$$Pe_{max} = \frac{0.04\,\frac{m}{yr} * 1\,\mathrm{m}}{\left(0.05\ \mathrm{m} * 0.04\frac{m}{yr} + 0.078894\ m^2/\mathrm{yr}\right)} = 0.5 \tag{7-2}$$

assuming Δz = a nominal 1 m, v_{max} = 0.04 m/yr (as determined from the A Farm and AX Farm non-tank representative flow field tables for Darcy flux and moisture content in Appendix D of RPP-RPT-60885[15]), α_L = 0.05 m (for silt dominated HSUs) and D* = 2.5×10^{-9} m^2/s or 0.078894 m^2/yr). Although the maximum Peclet number in the vadose zone during the first 100 years after the assumed closure of WMA A-AX exceeds the value indicated by Fletcher (1991) and PNNL-11216 as an upper limit, the first 100 years only represents 1% of the entire simulation, and about 5% of the time necessary for the ^{99}Tc concentration values in groundwater to reach a peak. Therefore, any numerical dispersion introduced during the first 100 years is assumed to have a negligible impact on the results.

The maximum Peclet in the Cold Creek gravel aquifer is estimated to range between ~0.41 for the minimum horizontal spacing of 4.355 m to ~1.9 for the maximum spacing of 20 m (Appendix C of RPP-RPT-60101). These relatively low values of Peclet number suggest that the saturated zone spatial discretization is adequate.

Table 7-19 presents the results of an evaluation of three Courant number limit specifications, 1, 10, and 25, and the maximum concentration of ^{99}Tc associated with two of the WMA A-AX representative tank sources identified in RPP-RPT-60885: tank 241-A-102 and tank 241-AX-101. The implementation of the Courant number limit in STOMP and eSTOMP imposes a limit on the size of the time step based on the model cell with the largest calculated Courant number. The specified Courant number criterion is an upper limit, and the Courant number in most model cells is less than the specified limit. The negligible differences in the results at the PoCals indicate that an overly restrictive Courant limit does not affect the solution and appears to be unwarranted, especially considering the improved efficiency in solution time when the Courant restriction is relaxed to 25. These evaluations indicate that the Courant criterion of 25 specified for the time discretization limit is adequate for the WMA A-AX PA process model.

7.1.2.4 Convergence Criteria. PETSc is currently the only approved solver option in CHPRC Build 6 of eSTOMP. eSTOMP includes the option to specify values other than the defaults for the PETSc convergence tolerances. As indicated in RPP-RPT-60101, it must be demonstrated

[14] Table D-3 in RPP-RPT-60885: Year 0, node 102 Darcy Flow Rate = 117.80 mm/yr (rounded). Table D-4 in RPP-RPT-60885: Year 0, node 102 Moisture Content = 0.1069 (rounded). Node 102 Darcy velocity = 117.80 mm/yr / 0.1069 / 1,000 mm/m = 1.1 m/yr (rounded).

[15] Table D-3 in RPP-RPT-60885: Year 100, node 33 Darcy Flow Rate = 7.5322 mm/yr. Table D-4 in RPP-RPT-60885: Year 100, node 33 Moisture Content = 0.1886. Node 33 Darcy velocity = 7.5322 mm/yr / 0.1886 / 1,000 mm/m = 0.04 m/yr (rounded).

that the PETSc solver convergence tolerances yield acceptable accuracy by showing that the results of some sample test cases are consistent with results obtained in serial STOMP.

The WMA A-AX PA process model specifies a relative convergence tolerance of 1.0000E-12 and an absolute convergence tolerance of 1.0000E-25. Table 7-20 presents a comparison between the results associated with tanks 241-A-102 and 241-AX-101 (the WMA A-AX representative tank sources identified in RPP-RPT-60885) obtained using eSTOMP and those obtained using the serial STOMP bi-conjugate gradient stabilized solver. The differences in the results are negligible. The results are consistent with those obtained using serial STOMP, and the STOMP convergence tolerances yield acceptable accuracy.

7.2 CONCLUSIONS

The results of the process model indicate that negligible concentrations of ^{99}Tc and ^{129}I occur in groundwater within the compliance time frame 1,000 years after closure. The combined or cumulative concentration of ^{99}Tc in groundwater from all of the sources at the 12 PoCals along the line of evaluation 100 m from WMA A-AX reaches a maximum at about 2,170 years after closure of about 77 pCi/L, which is almost a factor of 12 less than the EPA MCL. The highest peak concentration occurs within PoCal 5. The ^{99}Tc released from tanks 241-A-105 and 241-A-104 are the two largest components of that peak concentration. The contribution from each of those two tanks at this distance from WMA A-AX at the time of the peak concentration is more than three times the contribution of any other source.

The results of the process model indicate that the combined or cumulative concentration of ^{129}I in groundwater from all of the sources at the 12 PoCals along the line of evaluation 100 m from WMA A-AX reaches a maximum about 8,350 years after closure of about 0.002 pCi/L, which is about a factor of 500 less than the EPA MCL. The highest peak concentration occurs within PoCal 4. The ^{129}I released from the A Farm ancillary equipment, including pipelines, and tank 241-A-104 represent the two largest components of that peak concentration. The contribution from each of those two sources at this distance from WMA A-AX at the time of the peak concentration is about three times the contribution of any other source.

Results of model evaluation indicate that the model and model results satisfy the objective to estimate future contaminant concentrations in groundwater of ^{99}Tc and ^{129}I associated with waste remaining in tank residuals after closure of WMA A-AX. The process model provides benchmark results to assist in the development of the vadose and saturated zone system model (RPP-RPT-60885), which is intended to include the base case evaluation of all the radionuclides and contaminants of potential concern (RPP-CALC-62538). The process model evaluation demonstrates that eSTOMP produces the results necessary for benchmarking, the results are numerically stable, and the impacts of numerical dispersion are not large enough to negate the use of the model or its results for their intended purpose.

Table 7-19. Waste Management Area A-AX Performance Assessment Vadose Zone Courant Criteria Evaluation. (2 sheets)

	Numerical Dispersion Test Case Courant Number Specification = 1				Numerical Dispersion Test Case Courant Number Specification = 10				Process Model Courant Number Specification = 25			
	Source				Source				Source			
	241-A-102		241-AX-101		241-A-102		241-AX-101		241-A-102		241-AX-101	
	3,000 years of simulation completed in 576 hours on 4 processors		3,000 years of simulation completed in 563 hours on 4 processors		3,000 years of simulation completed in 101 hours on 4 processors		3,000 years of simulation completed in 99 hours on 4 processors		10,000 years of simulation completed in 172 hours on 4 processors		10,000 years of simulation completed in 194 hours on 4 processors	
Point of Calculation at the Fence Line of Waste Management Area A-AX	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**
1	4170	1	4470	2E-07	4170	1	4470	2E-07	4170	1	4470	2E-07
2	4170	4	4470	2E-06	4170	4	4470	2E-06	4170	4	4470	2E-06
3	4175	9	4470	3E-05	4175	9	4470	3E-05	4175	9	4470	3E-05
4	4175	8	4470	0.0004	4175	8	4470	0.0004	4175	8	4470	0.0004
5	4175	3	4470	0.006	4175	3	4470	0.006	4175	3	4470	0.006
6	4175	0.4	4470	0.1	4175	0.4	4470	0.1	4175	0.4	4470	0.1
7	4175	0.05	4485	2	4175	0.05	4485	2	4175	0.05	4485	2
8	4175	0.004	4500	6	4175	0.004	4500	6	4175	0.004	4500	6
9	4175	0.0003	4500	2	4175	0.0003	4500	2	4175	0.0003	4500	2

Table 7-19. Waste Management Area A-AX Performance Assessment Vadose Zone Courant Criteria Evaluation. (2 sheets)

	Numerical Dispersion Test Case Courant Number Specification = 1				Numerical Dispersion Test Case Courant Number Specification = 10				Process Model Courant Number Specification = 25			
	Source				Source				Source			
	241-A-102		241-AX-101		241-A-102		241-AX-101		241-A-102		241-AX-101	
	3,000 years of simulation completed in 576 hours on 4 processors		3,000 years of simulation completed in 563 hours on 4 processors		3,000 years of simulation completed in 101 hours on 4 processors		3,000 years of simulation completed in 99 hours on 4 processors		10,000 years of simulation completed in 172 hours on 4 processors		10,000 years of simulation completed in 194 hours on 4 processors	
Point of Calculation 100 meters from Waste Management Area A-AX	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**
1	4170	1	4480	2E-05	4170	1	4480	2E-05	4175	1	4480	2E-05
2	4175	3	4480	0.0002	4175	3	4480	0.0002	4175	3	4480	0.0002
3	4175	5	4480	0.001	4175	5	4480	0.001	4175	5	4480	0.001
4	4175	7	4485	0.01	4175	7	4485	0.01	4175	7	4485	0.01
5	4175	5	4485	0.07	4175	5	4485	0.07	4175	5	4485	0.07
6	4175	3	4490	0.4	4175	3	4490	0.4	4175	3	4490	0.4
7	4175	0.8	4490	1	4175	0.8	4490	1	4175	0.8	4495	1
8	4175	0.2	4495	2	4175	0.2	4495	2	4175	0.2	4495	2
9	4175	0.02	4495	2	4175	0.02	4500	2	4175	0.02	4500	2

Note: The gold highlighted cells are the only "Courant Number Specification = 10" and "Courant Number Specification = 25" results in the table that differ from the "Numerical Dispersion Test Case Courant Number Specification = 1" results, which were the basis results for comparison.

Table 7-20. Waste Management Area A-AX Performance Assessment Solution Stability Evaluation. (2 sheets)

	Numerical Stability Test Case Courant Number = 25 Serial STOMP Bi-Conjugate Gradient Stabilized Maximum Convergence Residual = 1.0000E-06				Process Model Courant Number = 25 eSTOMP PETSc Relative Convergence Tolerance = 1.0000E-12 Absolute Convergence Tolerance = 1.0000E-25			
	Source				Source			
	241-A-102		241-AX-101		241-A-102		241-AX-101	
	10,000 years of simulation completed in 288 hours		10,000 years of simulation completed in 321 hours		10,000 years of simulation completed in 172 hours		10,000 years of simulation completed in 194 hours	
Point of Calculation at the Fence Line of Waste Management Area A-AX	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**
1	4170	1	N/A	0	4170	1	4470	2E-07
2	4170	4	4470	2E-06	4170	4	4470	2E-06
3	4175	9	4470	3E-05	4175	9	4470	3E-05
4	4175	8	4470	0.0004	4175	8	4470	0.0004
5	4175	3	4470	0.006	4175	3	4470	0.006
6	4175	0.4	4470	0.1	4175	0.4	4470	0.1
7	4175	0.05	4485	2	4175	0.05	4485	2
8	4175	0.004	4500	6	4175	0.004	4500	6
9	4175	0.0003	4500	2	4175	0.0003	4500	2

Table 7-20. Waste Management Area A-AX Performance Assessment Solution Stability Evaluation. (2 sheets)

	Numerical Stability Test Case Courant Number = 25 Serial STOMP Bi-Conjugate Gradient Stabilized Maximum Convergence Residual = 1.0000E-06				Process Model Courant Number = 25 eSTOMP PETSc Relative Convergence Tolerance = 1.0000E-12 Absolute Convergence Tolerance = 1.0000E-25			
	Source				Source			
	241-A-102		241-AX-101		241-A-102		241-AX-101	
	10,000 years of simulation completed in 288 hours		10,000 years of simulation completed in 321 hours		10,000 years of simulation completed in 172 hours		10,000 years of simulation completed in 194 hours	
Point of Calculation 100 meters Downgradient of Waste Management Area A-AX	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**	**Year of Maximum Concentration**	**Maximum Concentration (pCi/L)**
1	4175	1	4480	2E-05	4175	1	4480	2E-05
2	4175	3	4480	0.0002	4175	3	4480	0.0002
3	4175	5	4480	0.001	4175	5	4480	0.001
4	4175	7	4485	0.01	4175	7	4485	0.01
5	4175	5	4485	0.07	4175	5	4485	0.07
6	4175	3	4490	0.4	4175	3	4490	0.4
7	4175	0.8	4495	1	4175	0.8	4495	1
8	4175	0.2	4495	2	4175	0.2	4495	2
9	4175	0.02	4500	2	4175	0.02	4500	2

Note: The gold highlighted cells are the only "eSTOMP" results that differ from the "Serial STOMP" results, which were the basis results for comparison.

Subsurface Transport Over Multiple Phases (STOMP) and Extreme-scale Subsurface Transport Over Multiple Phases (eSTOMP) are developed and distributed by Battelle Memorial Institute.

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RPP-RPT-59958, 2018, *Performance Assessment for the Integrated Disposal Facility, Hanford Site, Washington*, Rev. 1A, Washington River Protection Solutions, LLC, and INTERA, Inc., Richland, Washington.

RPP-RPT-60101, 2020, *Model Package Report Flow and Contaminant Transport Numerical Model Used in WMA A-AX Performance Assessment and RCRA Closure Analysis*, Rev. 0, CH2M HILL Plateau Remediation Company/INTERA, Inc./ TecGeo, Inc./Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60171, in process, *Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis*, Rev. 0, INTERA, Inc./TecGeo, Inc./CH2M HILL Plateau Remediation Company/Washington River Protection Solutions, LLC, Richland, Washington.

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APPENDIX A

LIST OF SOURCE RELEASE NODES

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APPENDIX A
LIST OF SOURCE RELEASE NODES

Source	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Beginning K Index	Ending K Index	Number of Source Release Time Steps	
							Tc-99	I-129
241-A-101	46	49	34	34	104	104	1901	1901
	45	50	35	35	104	104		
	45	50	36	36	104	104		
	45	50	37	37	104	104		
	45	50	38	38	104	104		
	46	49	39	39	104	104		
241-A-102	51	54	39	39	104	104	1901	1901
	50	55	40	40	104	104		
	50	55	41	41	104	104		
	50	55	42	42	104	104		
	50	55	43	43	104	104		
	51	54	44	44	104	104		
241-A-103	56	59	44	44	104	104	1901	1901
	55	60	45	45	104	104		
	55	60	46	46	104	104		
	55	60	47	47	104	104		
	55	60	48	48	104	104		
	56	59	49	49	104	104		
241-A-104	41	44	39	39	104	104	1901	1901
	40	45	40	40	104	104		
	40	45	41	41	104	104		
	40	45	42	42	104	104		
	40	45	43	43	104	104		
	41	44	44	44	104	104		
241-A-105	46	49	44	44	104	104	1901	1901
	45	50	45	45	104	104		
	45	50	46	46	104	104		
	45	50	47	47	104	104		
	45	50	48	48	104	104		
	46	49	49	49	104	104		

Source	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Beginning K Index	Ending K Index	Number of Source Release Time Steps	
							Tc-99	I-129
241-A-106	51	54	49	49	104	104	1901	1901
	50	55	50	50	104	104		
	50	55	51	51	104	104		
	50	55	52	52	104	104		
	50	55	53	53	104	104		
	51	54	54	54	104	104		
241-AX-101	36	39	74	74	102	102	1901	1901
	35	40	75	75	102	102		
	35	40	76	76	102	102		
	35	40	77	77	102	102		
	35	40	78	78	102	102		
	36	39	79	79	102	102		
241-AX-102	41	44	69	69	102	102	1901	1901
	40	45	70	70	102	102		
	40	45	71	71	102	102		
	40	45	72	72	102	102		
	40	45	73	73	102	102		
	41	44	74	74	102	102		
241-AX-103	31	34	69	69	102	102	1901	1901
	30	35	70	70	102	102		
	30	35	71	71	102	102		
	30	35	72	72	102	102		
	30	35	73	73	102	102		
	31	34	74	74	102	102		
241-AX-104	36	39	64	64	102	102	1901	1901
	35	40	65	65	102	102		
	35	40	66	66	102	102		
	35	40	67	67	102	102		
	35	40	68	68	102	102		
	36	39	69	69	102	102		

Source	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Beginning K Index	Ending K Index	Number of Source Release Time Steps	
							Tc-99	I-129
A Pipelines	47	48	27	27	116	116	512	118
	46	49	28	28	116	116		
	45	51	29	29	116	116		
	44	52	30	30	116	116		
	42	53	31	31	116	116		
	41	54	32	32	116	116		
	40	55	33	33	116	116		
	39	46	34	34	116	116		
	49	56	34	34	116	116		
	38	45	35	35	116	116		
	50	57	35	35	116	116		
	37	44	36	36	116	116		
	51	58	36	36	116	116		
	36	44	37	37	116	116		
	51	59	37	37	116	116		
	35	45	38	38	116	116		
	50	60	38	38	116	116		
	34	41	39	39	116	116		
	44	46	39	39	116	116		
	49	51	39	39	116	116		
	54	61	39	39	116	116		
	33	40	40	40	116	116		
	45	50	40	40	116	116		
	55	62	40	40	116	116		
	32	39	41	41	116	116		
	46	49	41	41	116	116		
	56	63	41	41	116	116		
	32	39	42	42	116	116		
	46	49	42	42	116	116		
	56	64	42	42	116	116		
	33	40	43	43	116	116		
	45	50	43	43	116	116		
	55	65	43	43	116	116		
	34	41	44	44	116	116		
	44	46	44	44	116	116		
	49	51	44	44	116	116		

Source	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Beginning K Index	Ending K Index	Number of Source Release Time Steps	
							Tc-99	I-129
A Pipelines	54	56	44	44	116	116	512	118
	59	65	44	44	116	116		
	35	45	45	45	116	116		
	50	55	45	45	116	116		
	60	66	45	45	116	116		
	36	44	46	46	116	116		
	51	54	46	46	116	116		
	61	67	46	46	116	116		
	37	44	47	47	116	116		
	51	54	47	47	116	116		
	61	67	47	47	116	116		
	38	45	48	48	116	116		
	50	55	48	48	116	116		
	60	66	48	48	116	116		
	39	46	49	49	116	116		
	49	51	49	49	116	116		
	54	56	49	49	116	116		
	59	65	49	49	116	116		
	40	50	50	50	116	116		
	55	65	50	50	116	116		
	41	49	51	51	116	116		
	56	64	51	51	116	116		
	42	49	52	52	116	116		
	56	63	52	52	116	116		
	43	50	53	53	116	116		
	55	62	53	53	116	116		
	44	51	54	54	116	116		
	54	61	54	54	116	116		
	45	60	55	55	116	116		
	46	59	56	56	116	116		
	48	58	57	57	116	116		
	49	57	58	58	116	116		
	50	55	59	59	116	116		
	52	54	60	60	116	116		
	53	53	61	61	116	116		

Source	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Beginning K Index	Ending K Index	Number of Source Release Time Steps	
							Tc-99	I-129
AX Pipelines	38	38	59	59	114	114	5	1271
	37	40	60	60	114	114		
	35	41	61	61	114	114		
	34	42	62	62	114	114		
	33	43	63	63	114	114		
	32	36	64	64	114	114		
	39	44	64	64	114	114		
	31	35	65	65	114	114		
	40	45	65	65	114	114		
	30	34	66	66	114	114		
	41	46	66	66	114	114		
	29	34	67	67	114	114		
	41	47	67	67	114	114		
	28	35	68	68	114	114		
	40	48	68	68	114	114		
	27	31	69	69	114	114		
	34	36	69	69	114	114		
	39	41	69	69	114	114		
	44	49	69	69	114	114		
	26	30	70	70	114	114		
	35	40	70	70	114	114		
	45	50	70	70	114	114		
	26	29	71	71	114	114		
	36	39	71	71	114	114		
	46	51	71	71	114	114		
	25	29	72	72	114	114		
	36	39	72	72	114	114		
	46	51	72	72	114	114		
	24	30	73	73	114	114		
	35	40	73	73	114	114		
	45	50	73	73	114	114		
	24	31	74	74	114	114		
	34	36	74	74	114	114		
	39	41	74	74	114	114		
	44	49	74	74	114	114		
	25	35	75	75	114	114		

Source	Beginning I Index	Ending I Index	Beginning J Index	Ending J Index	Beginning K Index	Ending K Index	Number of Source Release Time Steps	
							Tc-99	I-129
AX Pipelines	40	48	75	75	114	114	5	1271
	26	34	76	76	114	114		
	41	47	76	76	114	114		
	27	34	77	77	114	114		
	41	46	77	77	114	114		
	28	35	78	78	114	114		
	40	45	78	78	114	114		
	29	36	79	79	114	114		
	39	44	79	79	114	114		
	30	43	80	80	114	114		
	31	41	81	81	114	114		
	32	40	82	82	114	114		
	33	39	83	83	114	114		
	34	38	84	84	114	114		
	36	37	85	85	114	114		

ATTACHMENT 1

SOFTWARE INSTALLATION AND CHECKOUT FORMS

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

EXECUTABLE INFORMATION:

2. Executable Name (include path):

```
All executable files installed in directory [redacted]
--------------------------------  ---------------------------
MD5 File Signature                Executable File Name
--------------------------------  ---------------------------
6536b8e12d8c5b83dca76f2c947b6153  stomp-wae-bcg-chprc04i.x
e0cdf04bc1a2f6c55c5a1b499939f663  stomp-wae-bcg-chprc04l.x
6e72340bb39f6056e232fe5ff241c4d4  stomp-wae-bd-chprc04i.x
3f837a0fb8d9f47dbcada686f542d7fc  stomp-wae-bd-chprc04l.x
7e5b4cc36a8991b3d5a8ea2ed155ce47  stomp-wae-cgsq-chprc04i.x
00a898c0c3ec06817485781ad1c9ec46  stomp-wae-cgsq-chprc04l.x
f18ff5ab5667065d8ab12657344fb6a0  stomp-wae-cgst-chprc04i.x
061af86cf21ad8435b046d0efabe971b  stomp-wae-cgst-chprc04l.x
3c8111a9855dc0e430bf3c8a7abcf37e  stomp-w-bcg-chprc04i.x
20436d615a94955a2ce8eecdb8cba546  stomp-w-bcg-chprc04l.x
8b3df29df21d040189c3e2a50ef823bb  stomp-w-bd-chprc04i.x
066a289a75aedb933eb2536da5d7d1ff  stomp-w-bd-chprc04l.x
c8e62ad7a0d9b6fca39d8a8952ef5d8e  stomp-w-cgsq-chprc04i.x
28ad16806e1307aca51fd7bf89793e75  stomp-w-cgsq-chprc04l.x
6c25051016db2fe1f883a7caaaab1e97  stomp-w-cgst-chprc04i.x
ff9ff6f29b3469419ffaece87d7e772b  stomp-w-cgst-chprc04l.x
0c3e3fba40f5b93e71bcf9586432fd27  stomp-w-r-bcg-chprc04i.x
78492aee80a8c2d0a4e82aabf4a9c213  stomp-w-r-bcg-chprc04l.x
84b129786aba9c4be884e15e45a67389  stomp-w-r-bd-chprc04i.x
e990f1566c8099a8d54508de3da9cd88  stomp-w-r-bd-chprc04l.x
18a589a2b55aab2db290efea19b39351  stomp-w-r-cgsq-chprc04i.x
6569959476772a137df35ce874821889  stomp-w-r-cgsq-chprc04l.x
```

3. Executable Size (bytes): MD5 signatures above uniquely identify each executable file

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Tellus Subsurface Modeling Platform

5. Operating System (include version number):

   [redacted] 2.6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86_64 x86_64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Tellus Subsurface Modeling Platform

7. Operating System (include version number):

   [redacted].6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86_64 x86_64 GNU/Linux

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

8. Open Problem Report? (◉) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]

10. Procedure(s):

[redacted]

11. Libraries:

N/A (static linking)

12. Input Files:

Input files for ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-2

13. Output Files:

plot.* files produced by STOMP in testing

14. Test Cases:

ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-3

15. Test Case Results:

Pass for all executables identified above (two failed executables are documented in the Requirements Traceability Matrix and are not included in the installation).

16. Test Performed By: WJ McMahon

17. Test Results: (◉) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Accepted; Installation noted in HISI for users WE Nichols, TJ Budge, WJ McMahon, S Mehta.

Prepared By:

19.	William E Nichols	WE Nichols	24 Apr 2013
	Software Owner (Signature)	Print	Date

20. Test Personnel:

Will J McMahon	WJ McMahon	06 May 2013
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.		N/R (per CHPRC-00211 Rev 1)	
	Software SME (Signature)	Print	Date

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: eSTOMP (Parallel - Subsurf. Trans. Over Mult. Phases) Software Version No.: Bld 6

EXECUTABLE INFORMATION:

2. Executable Name (include path):

Test: [redacted]
Production: [redacted]
MD5 file signature: c4429b6a23dd26537f59d15594e5fc3f

3. Executable Size (bytes): 12824187

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

Tellus Subsurface Modeling Platform

5. Operating System (include version number):

Linux [redacted] 2.6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86 64 x86 64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

Tellus Subsurface Modeling Platform

7. Operating System (include version number):

Linux [redacted] .6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86 64 x86 64 GNU/Linux

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]

10. Procedure(s):

[redacted]

11. Libraries:

[redacted]

12. Input Files:

[redacted]

13. Output Files:

[redacted]

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: eSTOMP (Parallel - Subsurf. Trans. Over Mult. Phases) Software Version No.: Bld 6

14. Test Cases:

ATC-STOMP-1 (Water Mode with Transport) only

15. Test Case Results:

Pass

16. Test Performed By: WJ McMahon

17. Test Results: ◉ Satisfactory, Accepted for Use ◯ Unsatisfactory

18. Disposition (include HISI update):

Accepted; Installation noted in HISI for users WE Nichols, TJ Budge, WJ McMahon, S Mehta WEN

Prepared By:

19. [signature]	WE Nichols	1 OCT 2018
Software Owner (Signature)	Print	Date

20. Test Personnel:

William A. McMahon	WJ McMahon	10/01/18
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	N/R (per CHPRC-00211, Rev. 3)	
Software SME (Signature)	Print	Date

A-6005-149 (REV 0)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: Tecplot 360 Software Version No.: EX2017

EXECUTABLE INFORMATION:

2. Executable Name (include path):

[redacted]

3. Executable Size (bytes): 5.851 MB

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

N/A; COTS; Executable provided

5. Operating System (include version number):

N/A; COTS; Executable provided

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

WF37379

7. Operating System (include version number):

Windows 10 Enterprise

8. Open Problem Report? ◉ No ◯ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]

10. Procedure(s):

[redacted]

11. Libraries:

[redacted]

12. Input Files:

[redacted]

13. Output Files:

[redacted]

14. Test Cases:

[redacted]

15. Test Case Results:

[redacted]

16. Test Performed By: W. J. McMahon

17. Test Results: ◉ Satisfactory, Accepted for Use ◯ Unsatisfactory

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: Tecplot 360 Software Version No.: EX2017

18. Disposition (include HISI update):

Prepared By: WILLIAM NICHOLS (Affiliate) Digitally signed by WILLIAM NICHOLS (Affiliate) Date: 2020.09.24 10:29:18 -07'00'

	Signature	Print	Date
19.		W. E. Nichols	
	Software Owner (Signature)	Print	Date

20. Test Personnel:

Sign	Print	Date
WILLIAM MCMAHON (Affiliate) Digitally signed by WILLIAM MCMAHON (Affiliate) Date: 2020.09.24 08:29:13 -07'00'	W. J. McMahon	

Approved By:

	Signature	Print	Date
21.	Donna Morgans Digitally signed by Donna Morgans Date: 2020.09.24 11:32:13 -07'00'	D. L. Morgans	
	Software SME (Signature)	Print	Date

ATTACHMENT 2

SOFTWARE OPTIONS ANALYSIS

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STOMP Option NQA-1 Status Check				
Input Files: "input_ss_tct_03_rch_02_sat_03_bcs090_estomp_petsc_tol" and "input_ss_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol" (McMahon; Water Only Steady State Approximation Initialization Input File)				
Option status check by: WJ McMahon, 03/07/2019				
Input Card	**Input Parameter**	**Input Option**	**NQA-1 Tested?**	**Comment**
Simulation Title	Simulation Title	—	Yes	
Simulation Title	Simulation Documentation Information	—	Yes	
Solution Control	Execution Mode Option	normal w/ petsc,1.0E-12,1.0E-25,,	Yes	Only in input_ss_tct_03_rch_02_sat_03_bcs090_estomp_petsc_tol
Solution Control	Execution Mode Option	restart file w/petsc, ./restart, 1.0E-12, 1.0E-25,	Yes	Only in input_ss_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol
Solution Control	Operational Mode Options	Water	Yes	
Solution Control	Interfacial Averaging Options	Default (all)	Yes	
Grid	Method of Grid Input	(Non-uniform) Cartesian	Yes	
Grid	Grid Spacing Specification Option	Count and Cell Size	Yes	
Rock/Soil Zonation	Method of Zonation	External File	Yes	
Inactive Nodes	Declaration of Inactive Nodes	External File	Yes	
Mechanical Properties	Compressibility Option	Pore Compressibility	Yes	
Mechanical Properties	Tortuosity Function	Millington and Quirk	Yes	
Hydraulic Properties	Method of Hydraulic Property Input	Hydraulic Conductivity	Yes	

Saturation Function	Saturation Function Option	Nonhysteretic van Genuchten	Yes	"Nonhysteretic" is no longer a recognized keyword and is ignored according to the output files. The description the van Genuchten (1980) retention function presented on the STOMP User Guide page is nonhysteretic.
Aqueous Relative Permeability	Relative Permeability Option	Modified Mualem	Yes	
Initial Conditions	Initial Aqueous Pressure	Aqueous Pressure-Gas Pressure	Yes	
Initial Conditions	Method of Initial Condition Input	Direct Input	Yes	Initial condition values are only included in input_ss_tct_03_rch_02_sat_03_bcs090_estomp_petsc_tol
Initial Conditions	Method of Initial Condition Input	Restart	Yes	Only in input_ss_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol
Boundary Conditions	Aqueous Boundary Condition Options	Neumann	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Seepage Face	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Initial Condition	Yes	Only in input_ss_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol
Output Control	Reference Node Output	Aqueous Saturation	Yes	
Output Control	Reference Node Output	Aqueous Pressure	Yes	
Output Control	Reference Node Output	Aqueous Moisture Content	Yes	
Output Control	Reference Node Output	XNC Aqueous Volumetric Flux	Yes	

Output Control	Reference Node Output	ZNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	Final Restart	N/A	Final Restart is not included in the list of variables. Final Restart is not a variable but a flag indicating that a restart file is only created at the end of the simulation. All other specified variables are identified as NQA-1 tested.
Output Control	Plot File Output	Rock/Soil type	Yes	
Output Control	Plot File Output	Aqueous Saturation	Yes	
Output Control	Plot File Output	Aqueous Pressure	Yes	
Output Control	Plot File Output	Aqueous Moisture Content	Yes	
Output Control	Plot File Output	XNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	YNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	ZNC Aqueous Volumetric Flux	Yes	
Surface Flux	Surface Output File Options	Multiple Surface Output Files	Yes	
Surface Flux	Defining Surfaces for the Output Fluxes	Range of Node Indices	Yes	
Surface Flux	Surface Output Flux Types	Aqueous Volumetric Flux	Yes	

STOMP Option NQA-1 Status Check				
Input File: " input_op_tct_03_rch_02_sat_03_bcs091_estomp_petsc_tol " (McMahon; Water Only Transient Operations Period Input File)				
Option status check by: WJ McMahon, 03/07/2019				
Input Card	**Input Parameter**	**Input Option**	**NQA-1 Tested?**	**Comment**
Simulation Title	Simulation Title	—	Yes	
Simulation Title	Simulation Documentation Information	—	Yes	
Solution Control	Execution Mode Option	restart file w/petsc, ./restart, 1.0E-12, 1.0E-25,	Yes	
Solution Control	Operational Mode Options	Water	Yes	
Solution Control	Interfacial Averaging Options	Default (all)	Yes	
Grid	Method of Grid Input	(Non-uniform) Cartesian	Yes	
Grid	Grid Spacing Specification Option	Count and Cell Size	Yes	
Rock/Soil Zonation	Method of Zonation	External File	Yes	
Inactive Nodes	Declaration of Inactive Nodes	External File	Yes	
Mechanical Properties	Compressibility Option	Pore Compressibility	Yes	
Mechanical Properties	Tortuosity Function	Millington and Quirk	Yes	
Hydraulic Properties	Method of Hydraulic Property Input	Hydraulic Conductivity	Yes	

Saturation Function	Saturation Function Option	Nonhysteretic van Genuchten	Yes	"Nonhysteretic" is no longer a recognized keyword and is ignored according to the output files. The description the van Genuchten (1980) retention function presented on the STOMP User Guide page is nonhysteretic.
Aqueous Relative Permeability	Relative Permeability Option	Modified Mualem	Yes	
Initial Conditions	Initial Aqueous Pressure	Aqueous Pressure-Gas Pressure	Yes	No initial condition values are included in this input file.
Initial Conditions	Method of Initial Condition Input	Restart	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Neumann	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Seepage Face	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Initial Condition	Yes	
Output Control	Reference Node Output	Aqueous Saturation	Yes	
Output Control	Reference Node Output	Aqueous Pressure	Yes	
Output Control	Reference Node Output	Aqueous Moisture Content	Yes	
Output Control	Reference Node Output	XNC Aqueous Volumetric Flux	Yes	
Output Control	Reference Node Output	ZNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	Final Restart	N/A	Final Restart is not included in the list of variables. Final Restart is not a variable but a flag indicating that a restart file is only created at the end of the simulation.

				All other specified variables are identified as NQA-1 tested.
Output Control	Plot File Output	Rock/Soil Type	Yes	
Output Control	Plot File Output	Aqueous Saturation	Yes	
Output Control	Plot File Output	Aqueous Pressure	Yes	
Output Control	Plot File Output	Aqueous Moisture Content	Yes	
Output Control	Plot File Output	XNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	YNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	ZNC Aqueous Volumetric Flux	Yes	
Surface Flux	Surface Output File Options	Multiple Surface Output Files	Yes	
Surface Flux	Defining Surfaces for the Output Fluxes	Range of Node Indices	Yes	
Surface Flux	Surface Output Flux Types	Aqueous Volumetric Flux	Yes	

STOMP Option NQA-1 Status Check				
Input File: See list of post-closure input files that are certified to use the options identified in this form (McMahon; Water with Transport Transient Post-Closure Period Input File)				
Option status check by: WJ McMahon, 03/07/2019				
Input Card	**Input Parameter**	**Input Option**	**NQA-1 Tested?**	**Comment**
Simulation Title	Simulation Title	—	Yes	
Simulation Title	Simulation Documentation Information	—	Yes	
Solution Control	Execution Mode Option	restart file w/petsc, ./restart, 1.0E-12, 1.0E-25	Yes	
Solution Control	Operational Mode Options	Water with Transport and Courant	Yes	
Solution Control	Interfacial Averaging Options	Default (all)	Yes	
Grid	Method of Grid Input	(Non-uniform) Cartesian	Yes	
Grid	Grid Spacing Specification Option	Count and Cell Size	Yes	
Rock/Soil Zonation	Method of Zonation	External File	Yes	
Inactive Nodes	Declaration of Inactive Nodes	External File	Yes	
Mechanical Properties	Compressibility Option	Pore Compressibility	Yes	
Mechanical Properties	Tortuosity Function	Millington and Quirk	Yes	
Hydraulic Properties	Method of Hydraulic Property Input	Hydraulic Conductivity	Yes	

Saturation Function	Saturation Function Option	Nonhysteretic van Genuchten	Yes	"Nonhysteretic" is no longer a recognized keyword and is ignored according to the output files. The description the van Genuchten (1980) retention function presented on the STOMP User Guide page is nonhysteretic.
Aqueous Relative Permeability	Relative Permeability Option	Modified Mualem	Yes	
Initial Conditions	Initial Aqueous Pressure	Aqueous Saturation-Aqueous Pressure	N/A	No initial condition values are included in this input file.
Initial Conditions	Method of Initial Condition Input	Restart	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Neumann	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Seepage Face	Yes	
Boundary Conditions	Aqueous Boundary Condition Options	Initial Condition	Yes	
Boundary Conditions	Solute Boundary Condition Options	Outflow	Yes	
Solute/Fluid Interactions	Effective Diffusion Options	Conventional	Yes	
Solute/Fluid Interactions	Solid/Aqueous Partition Options	Continuous	Yes	
Solute/Fluid Interactions	Reaction Options	Radioactive Decay	Yes	
Solute/Porous Media Interactions	Dispersivity/ Partitioning Coefficient	Explicit	Yes	
Output Control	Plot File Output	Rock/Soil type	Yes	
Output Control	Reference Node Output	Aqueous Saturation	Yes	
Output Control	Reference Node Output	Aqueous Pressure	Yes	
Output Control	Reference Node Output	Aqueous Moisture Content	Yes	

Output Control	Reference Node Output	XNC Aqueous Volumetric Flux	Yes	
Output Control	Reference Node Output	ZNC Aqueous Volumetric Flux	Yes	
Output Control	Reference Node Output	Solute Integrated Mass	Yes	
Output Control	Reference Node Output	Solute Aqueous Concentration	Yes	
Output Control	Plot File Output	Rock/Soil Type	Yes	
Output Control	Plot File Output	Aqueous Saturation	Yes	
Output Control	Plot File Output	Aqueous Pressure	Yes	
Output Control	Plot File Output	Aqueous Moisture Content	Yes	
Output Control	Plot File Output	XNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	ZNC Aqueous Volumetric Flux	Yes	
Output Control	Plot File Output	Solute Aqueous Concentration	Yes	
Output Control	Plot File Output	Solute Volumetric Concentration	Yes	
Output Control	Plot File Output	Final Restart	N/A	Final Restart is not included in the list of variables. Final Restart is not a variable but a flag indicating that a restart file is only created at the end of the simulation. All other specified variables are identified as NQA-1 tested.
Surface Flux	Surface Output File Options	Multiple Surface Output Files	Yes	
Surface Flux	Defining Surfaces for the Output Fluxes	Range of Node Indices	Yes	
Surface Flux	Surface Output Flux Types	Aqueous Volumetric Flux	Yes	
Surface Flux	Surface Output Flux Types	Solute Flux	Yes	

Post-closure input files that are certified to use the options identified in STOMP Option NQA-1 Status Check Form:

input_pc_tct_03_rch_02_sat_03_bcs091_tc99_a_102_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_a_pip_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_ax101_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_ax_pip_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_b_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_c_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_d_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_e_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_f_inv_06_ccu_18_aqc25_e_p_t_z

input_pc_tct_03_rch_02_sat_03_bcs091_i129_a_102_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_i129_ax101_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_i129_b_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_i129_c_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_i129_d_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_i129_e_inv_06_ccu_18_aqc25_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_i129_f_inv_06_ccu_18_aqc25_e_p_t_z

input_pc_tct_03_rch_02_sat_03_bcs091_tc99_a_102_inv_06_ccu_18_aqc01_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_a_102_inv_06_ccu_18_aqc10_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_ax101_inv_06_ccu_18_aqc01_e_p_t_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_ax101_inv_06_ccu_18_aqc10_e_p_t_z

input_pc_tct_03_rch_02_sat_03_bcs091_tc99_a_102_inv_06_ccu_18_aqc25_z
input_pc_tct_03_rch_02_sat_03_bcs091_tc99_ax101_inv_06_ccu_18_aqc25_z

ATTACHMENT 3

EMCF CHECK LOG

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RPP-CALC-63164, Rev. 0

EMCF CHECK LOG
Checks performed and results:

CHECKER LOG FOR PROCESS MODELS					
Project and Environmental Model Calculation Specific Information:					
Project: WMA A-AX Performance Assessment					
Responsible Manager or Designee, and Position: Robert Hiergesell					
Originating Group or Department:				Date: 7/19/19	
Environmental Model Calculation File Report and Revision No.: RPP-CALC-63164 Draft A					
Environmental Model Calculation File Title: WMA A-AX PA Contaminant Fate and Transport Process Model					
Check: Environmental Model Calculation File Document Elements					
	List where Information is Described *(EMCF Section Number)*	Is the Description Correct and Sufficient?			Checker Signature
		Yes	No	If No, describe deficiency:	
Purpose	1	◉	○		Arun K. Wahi
Calculation Approach	3.4 and 4	◉	○		Arun K. Wahi
Assumptions	4 (citing RPP-RPT-60101)	◉	○		Arun K. Wahi
Inputs *(reference detailed checklist below as well)*	4.3 and 4.4	◉	○		Arun K. Wahi
Equations used	3.3 re: van G.-Mualem, Richards, and A-D equations solved by finite difference in STOMP/ eSTOMP 3.4.2 (verbal) for concentrations from fluxes and superposition 3.4.3.3 for Cr and Pe estimation Table 4-3 for initial condition pressure; Section 4.3.2 for van G. m and Sr; Table 4-8 for boundary condition pressure; Section 4.3.5 (verbal algorithm) for conversion of source release terms to per node basis and truncation of AE release instructions 7.1.2.2 and tables	◉	○		Arun K. Wahi

CHECKER LOG FOR PROCESS MODELS (Continued)

	List where Information is Described *(EMCF Section Number)*	Is the Description Correct and Sufficient? Yes	No	If No, describe deficiency:	Checker Signature
	therein for mass balance metrics 7.1.2.3 for example Darcy velocity estimates				
Conclusions	7.2	◉	○		Arum K. Walri
References	8	◉	○		Arum K. Walri

Check: Controlled Software Use

	List where Information is Described *(EMCF Section Number)*	Is the Criteria Met? Yes	No	If No, describe deficiency:	Checker Signature
Software used in the calculation is appropriate for application	5	◉	○		Arum K. Walri
Software use is approved and properly validated in accordance with approved software management plan	5	◉	○		Arum K. Walri
Software use is properly documented	5	◉	○		Arum K. Walri
Verify data was input correctly to approved software or spreadsheets	7. Limited to post-processing of the STOMP results for Section 7 Tables and Figures. See verification inform-ation under Further Checks Section	◉	○		Michael P. Connelly Digitally signed by Michael Connelly Date: 2019.07.19 15:09:42 -06'00'
If a spreadsheet is used, verify inputs/outputs of calculation(s) to ensure accuracy	7. Limited to post-processing of the STOMP results for Section 7 Tables and Figures. See verification inform-ation under Further Checks Section	◉	○		Michael P. Connelly Digitally signed by Michael Connelly Date: 2019.07.19 15:10:24 -06'00'

Check: Perform Calculation to Verify Free of Errors

	Describe how calculation was performed	List any discrepancies encountered *(If none, enter "None")*	Checker Signature
Perform the environmental model calculation as described to verify it is free of errors	7. Limited to post-processing of the STOMP results for Section 7 Tables and Figures. See verification inform-ation under Further Checks Section	None	Michael P. Connelly Digitally signed by Michael Connelly Date: 2019.07.19 15:11:15 -06'00'

CHECKER LOG FOR PROCESS MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Check: Process Model Parameterization *(Specify Values and Units in Each Column)*			
Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Simulation duration: Historic	(Section 3.4.1) 3000 years for ss, operations 1943-2050	yes, RPP-RPT-58693 for assumed closure	yes
Simulation duration: Predictive	(Section 3.4.1) 2050-12050; (Section 4.4) Courant number tests 2050-5050	yes, Section 4.3 in RPP-RPT-60101	yes
Boundary conditions: Recharge	(Sections 3.4.1 and 4.3.3, Tables 3-1 and 4-8 through 4-11) <1943, 3.5 mm/y; 1943-2050, Table 4-10; tank farms 0.5 mm/y 2050-2550, 3.5 mm/y 2550-12050; disturbed areas 63 mm/y 2050-2080, linear decrease to 3.5 mm/y by 2110, 3.5 mm/y 2110-12050	yes, Table 3-5 in RPP-RPT-60101 for rates, Figure 4-3 of RPP-RPT-58693 for timing until closure	yes
Boundary conditions: River	N/A	N/A	N/A
Boundary conditions: Head Dependent	(Tables 4-8 to 4-11) SE boundary 217583.25 Pa layer k6 w/ "seepage face" up to layer 19; NE and SW boundaries k6-k19 no flow to SS, then "initial condition"	yes, k6 P corresponds to head in Table 4-1 of RPP-RPT-60101	yes
Boundary Conditions: Specified Flux	(Tables 4-8 to 4-11) NW boundary CCG 0.139 m/d, RUA 7.64E-6 m/d	yes, Table 4-1 in RPP-RPT-60101	yes
Initial Conditions: Hydraulic	Table 4-3	yes, pp. C-33 and D-3 in RPP-RPT-60101 for head	yes
Initial Conditions: Contaminant	(Section 3.4.1) zero mass in domain until 2050	N/A	yes
Sources and Sinks: Aqueous Mass	N/A	N/A	N/A
Sources and Sinks: Contaminant Mass	(Section 4.3.5) source release timeseries from Goldsim simulations with adjustments to prescribe releases per node in STOMP	N/A, GoldSim_A AX_Release_Curves_Tc99_I129_U238_20181220.xlsx from system model team was used directly as input to preprocessing	yes, independently transformed source releases from GoldSim per procedure in EMCF and matched to eSTOMP input within

CHECKER LOG FOR PROCESS MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
	input	(checker independently verified preprocessing of original spreadsheet columns matched input)	relative difference at each time step of 0 to 0.10%, which is attributed to infrequent roundoff in last decimal place during electronic data format changes, and which is insignificant to the calculation
Hydraulic Properties: Conductivity	Table 4-5	yes, Tables 3-3 and 3-9 in RPP-RPT-60101	yes
Hydraulic Properties: Porosity	Table 4-4	yes, Tables 3-2 and 3-9 in RPP-RPT-60101	yes
Hydraulic Properties: Water Retention *(Vadose Only)*	Table 4-6, Table 4-7	yes, Tables 3-2 and 3-3 in RPP-RPT-60101	yes
Hydraulic Properties: Formation Density	Table 4-4 (particle density)	yes, Table 3-4 in RPP-RPT-60101 -- insignificant last digit difference silt particle density 2.82 vs. 2.83 in source	yes
Transport Properties: Diffusion	(Table 4-12) 2.5E-5 cm^2/s	yes, Section 3.1.4.5.3 in RPP-RPT-60101	yes
Transport Properties: Dispersivity	Table 4-13	yes, Tables 3-4 and 3-9 in RPP-RPT-60101	yes
Transport Properties: Sorption *(typically K_d)*	Table 4-13	yes, Table 3-8 in RPP-RPT-60101	yes (I-129 Kds in some input files are rounded vs. Table 4-13 as noted in the table)
Transport Properties: Radioactive Decay Rate	(Table 4-12) Tc-99 2.111E5 yr, I-129 1.57E7 yr	yes, ICRP 107 as cited in Section 3.1.6 in RPP-RPT-60101	yes
Check: Further Checks ***(Record additional checks performed and results)***			
Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Inventory: Radiological Decay Correction. Does the inventory *(source term)* include radionuclides, and if so, is it decay-corrected to the appropriate date for inclusion as a source?	Yes and yes. Source term is generated by GoldSim calculation which decay-corrects modeled inventory release between assumed closure date	(see Sources and Sinks: Contaminant Mass)	(see Sources and Sinks: Contaminant Mass)

CHECKER LOG FOR PROCESS MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
	in 2050 and end of 10,000-yr simulation time used in STOMP. Inventory at 2050 was decay-corrected in RPP-CALC-61032.		
Source release preprocessing verification and selected text and table checks for input sections saved in RPP-CALC-63164_checking_akw.xlsx. No discrepancies except rounding where noted.	N/A	N/A	N/A
Output figures and tables checking results continued on following pages.	N/A	N/A	N/A

CHECKER LOG FOR PROCESS MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Figure Type	Figure Number (Document)	Figure Reproducible/ Figure Errors Please note all figures were repro-duced independently of Figure in the document using the original data from the STOMP model. Please Note File: Section07_Figures.pdf contains all independently reproduced figures	Checked by
Breakthrough Curve	7-1 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-2 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-3 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-4 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-5 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-6 (Draft A)	Reproducible/Correct	M. P. Connelly
Contour Plot (WMA A/AX)	7-7 (Draft A)	Reproducible/Correct	M. P. Connelly
Contour Plot (A-102)	7-8 (Draft A)	Reproducible/Correct	M. P. Connelly
Contour Plot (A-105)	7-9 (Draft A)	Reproducible/Correct	M. P. Connelly
Contour Plot (AX-101)	7-10 (Draft A)	Reproducible/Correct	M. P. Connelly
Flux at Water Table Tc	7-11 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-12 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-13 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-14 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-15 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-16 (Draft A)	Reproducible/Correct	M. P. Connelly
Breakthrough Curve	7-17 (Draft A)	Reproducible/Correct	M. P. Connelly
Contour Plot (WMA A/AX)	7-18 (Draft A)	Reproducible/Correct	M. P. Connelly
Flux at Water Table	7-19 (Draft A)	Reproducible/Correct	M. P. Connelly
1-D Moisture Compar.	7-20 (Draft A)	Reproducible/Correct	M. P. Connelly
1-D Moisture Compar.	7-21 (Draft A)	Reproducible/Correct	M. P. Connelly

CHECKER LOG FOR PROCESS MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Table Subject	Table Number	Table Reproducible/ Table Errors Please note tables 7-1 through 7-12, 7-19 and 7-20 were reproduced using the original data from the STOMP in Tecplot making use of Aux Data to identify max value and time associated with max value and compared to the table in the document. Mass balance tables (7-13 - 7-18) spot checked values and verified	Checker: Checks are also provided in the following spreadsheets: tbl_7_01_through 7_12_checked_rpt_calc_63164_mpc.xslx and tbl_7_19courant_through_7_20stab__checked_rpt_calc_63164_mpc.xlsx
Max Concentration for WMA A/AX and PoCs FL	Table 7-1	Exact Match no errors	M. P. Connelly
Max Concentration for WMA A/AX and PoCs 100m	Table 7-2	Exact Match no errors	M. P. Connelly
Max Concentration for WMA A/AX and PoCs 200m	Table 7-3	Exact Match no errors	M. P. Connelly
PoC for Each Source's Max Value at FL	Table 7-4	Exact Match no errors	M. P. Connelly
PoC for Each Source's Max Value at 100m	Table 7-3	Exact Match no errors	M. P. Connelly
MPoC for Each Source's Max Value at 200m	Table 7-6	Exact Match no errors	M. P. Connelly
Max Tc-99 Conc and PoC for Each Source at FL	Table 7-7	Exact Match no errors	M. P. Connelly
Max Tc-99 Conc and PoC for Each Source at 100m	Table 7-8	Exact Match no errors	M. P. Connelly
Max Tc-99 Conc and PoC for Each Source at 200m	Table 7-9	Exact Match no errors	M. P. Connelly
Max I-129 Conc and PoC for Each Source at FL	Table 7-10	Exact Match no errors	M. P. Connelly
Max I-129 Conc and PoC for Each Source at FL	Table 7-11	Exact Match no errors	M. P. Connelly
Max I-129 Conc and PoC for Each Source at FL	Table 7-12	Exact Match no errors	M. P. Connelly
SS mass water balance	Table 7-13	Values were verified in spreadsheet: tbl_7_13_surface_mass_balance_ss_verified_rpt_calc_63164_mpc.xlsx	M. P. Connelly

CHECKER LOG FOR PROCESS MODELS (Continued)

Model Parameter Type	(1) Input Documented in EMCF?	(2) Values checked against parameter source?	(3) Input in EMCF matches model input file(s)?
Operational water mass balance	Table 7-14	Values were verified in spreadsheet: tbl_7_14_surface_mass_balance_op_verified_rpt_calc_63164_mpc.xlsx	M. P. Connelly
Post Closure water mass balance	Table 7-15	Values were verified in spreadsheet: tbl_7_15_through_7_17_Tc99_mass_balance_verified_rpt_calc_63164 mpc.xlsx	M. P. Connelly
Tc-99 mass balance year 4220	Table 7-16	Values were verified in spreadsheet: tbl_7_15_through_7_17_Tc99_mass_balance_verified_rpt_calc_63164 mpc.xlsx	M. P. Connelly
Tc-99 mass balance year 12050	Table 7-17	Values were verified in spreadsheet: tbl_7_15_through_7_17_Tc99_mass_balance_verified_rpt_calc_63164 mpc.xlsx	M. P. Connelly
I-129 mass balance year 12050	Table 7-18	Values were verified in spreadsheet: tbl_7_18_I129_mass_balance_verified_rpt_calc 63164 mpc.xlsx	M. P. Connelly
Courant Criteria	Table 7-19	Exact Match no errors	M. P. Connelly
Stability Evaluation	Table 7-20	Exact Match no errors	M. P. Connelly